This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

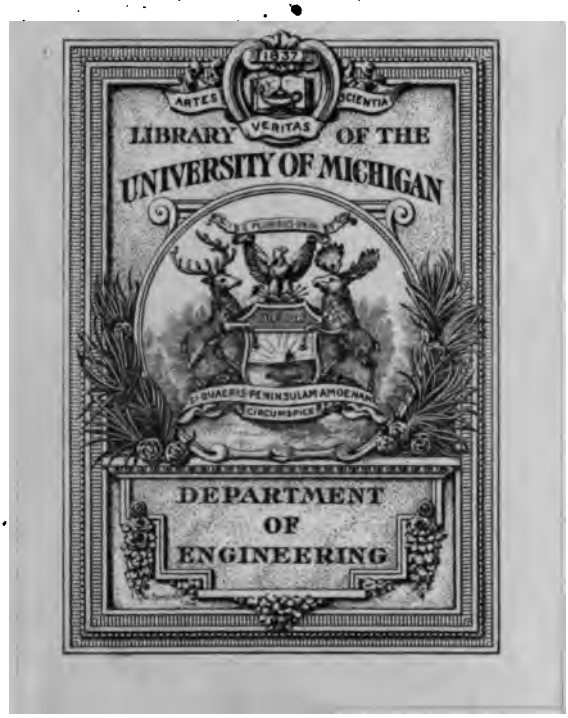
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 1,143,787

1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE
DEPARTMENT
OF
ENGINEERING

LIBRA...
VM
1
.N87


1837
ARTES
SCIENTIA
VERITAS
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
TUEBOR SUSTINET
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE
DEPARTMENT
OF
ENGINEERING

LIBRARY
VM
1
.N87

TRANSACTIONS

OF THE

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

EDITED BY THE SECRETARY OF THE INSTITUTION.

VOLUME XIV.

FOURTEENTH SESSION, 1897-98.

THE RIGHT OF PUBLICATION AND TRANSLATION IS RESERVED.

LONDON AND NEWCASTLE-UPON-TYNE:
ANDREW REID & COMPANY, LIMITED, PRINTERS AND PUBLISHERS.

1898.

ADVERTISEMENT.

"The Institution merely places on record, and is not, as a body, responsible for the statements or opinions advanced in the Papers read, or the Discussions thereon, which occur at the Meetings during the Session."

ERRATA.

Page 100,	line 4,	*for*	7,210	*read*	112,166.
„	„ 6,	„	3,605	„	56,083.
„	„ 9,	„	151	„	2,350.
„	„ 9,	„	8·75	„	136.
„	„ 20,	„	14,600	„	227,240.

Page 147, line 25, *for* Plate XIV. *read* Plate IX.

CONTENTS OF VOLUME XIV.

FOURTEENTH SESSION, 1897-98.

	PAGE.
Alphabetical List of Names of Writers of Papers and Speakers	vi
List of Publications added to Library	viii
„ Officers, 1897-98	xiii
„ Committees, etc., 1897-98	xiv
„ Honorary Members...	xv
„ Members, July, 1898	xv
„ Associates, „	xxxviii
„ Graduates, „	xlii
Constitution and Bye-Laws	xlix
Supplementary Bye-Laws relating to Graduate Section	lxvii
Library and Reading Room Rules...	lxx
Proceedings at General Meetings	1, 29, 73, 129, 161, 187, 213, 241
Council Report for Thirteenth Session	5
Financial Statement	8
INSTITUTION DINNER	121
Sessional Awards	30, 162
Visit to the Hartlepool Engine Works	69
Closing Business of the Session	253

PAPERS READ DURING THE SESSION.

1897.	
Nov. 5th.—"THE COMPARISON AND CONSTRUCTION OF SHIPS' LINES," by Mr. Archibald Hogg	15
Discussion	22
Dec. 6th.—Discussion continued	33
1898.	
Feb. 18th.—Mr. Archibald Hogg's Reply	131
1897.	
Dec. 6th.—"THE THEORY OF THE CENTRIFUGAL PUMP AND FAN," by Mr. C. H. Innes, M.A.	43
Discussion	66
1898.	
Feb. 18th.—Discussion continued	135
Mr. C. H. Innes's Reply	135
Jan. 15th.—"WATER BALLASTING OF STEAMERS," by Mr. Archibald McGlashan	77
Discussion	84
Feb. 18th.—Discussion continued	141
Mr. A. McGlashan's Reply	148

152767

1898. PAGE.

Jan. 15th.—"SOME CONSIDERATIONS IN CONNECTION WITH THE TRANSVERSE FRAMING OF SHIPS," by Mr. H. E. J. Camps ... 97
Discussion 118
Mar. 18th.—Discussion continued 163
April 18th.—Mr. H. E. J. Camps's Reply 191
Feb. 18th.—"AN INSTRUMENT FOR GAUGING THE CIRCULARITY OF BOILER FURNACES AND CYLINDERS AND PRODUCING A DIAGRAM," by Mr. T. Messenger 155
Discussion 159
Mar. 18th.—"SOME POINTS OF INTEREST IN THE DESIGNING OF CARGO STEAMERS," by Mr. A. E. Long, M.A. 173
Discussion 182
April 18th.—Discussion continued 195
May 13th.—Mr. A. E. Long's Reply 243
April 18th.—"CYLINDER RATIOS," by Mr. James Andrews 199
Discussion 211
April 26th.—Discussion continued 215
May 13th.—Mr. James Andrews's Reply 247
April 26th.—"THE EFFECTS OF DIFFERENT ARRANGEMENTS OF CRANK ANGLES UPON THE ECONOMY OF QUADRUPLE EXPANSION ENGINES," by Mr. A. L. Mellanby, B.Sc. 227
Discussion 233
May 13th.—Discussion continued 251
Mr. A. L. Mellanby's Reply 251
Communication from Mr. George Dykes on "A RELIABLE METHOD OF OBTAINING THE NECESSARY DISPLACEMENT AND CENTRE OF BUOYANCY OF SHIPS" 237

LIST OF PLATES.

PLATES TO ILLUSTRATE PAPERS ON—	PLATES.
"The Comparison and Construction of Ships' Lines"	I. to IV., XV.
"The Theory of the Centrifugal Pump and Fan"	V. to VII.
"Water Ballasting of Steamers"	VIII., IX.
"The Transverse Framing of Ships" ...	X. to XIV., XVIII., XIX.
"Instrument for Gauging the Circularity of Boiler Furnaces," etc.	XVI., XVII.
"The Designing of Cargo Steamers"	XX.
"Cylinder Ratios"	XXI. to XXVI.
"Different Arrangement of Crank Angles" ...	XXVII. to XXXI.
"The Displacement and Centre of Buoyancy of Ships"	XXXII., XXXIII.

ALPHABETICAL LIST OF WRITERS OF PAPERS AND SPEAKERS.

Name.	Name of Paper or Subject under Discussion.	Page.
Adamson, L. W. ...	Institution Dinner	125
Alexander, F. H. ...	The Designing of Cargo Steamers	195
Andrew, D.	The Designing of Cargo Steamers	184
Andrews, James ...	Cylinder Ratios	199
" ...	Reply to the Discussion on Cylinder Ratios ...	247
Arnison, G. N.	Comparison and Construction of Ships' Lines ...	26
"	Water Ballasting of Steamers	93
Batey, J. T.	Water Ballasting of Steamers	142
Black, J.	Water Ballasting of Steamers	89
Boyd, W.	Institution Dinner	124
"	Alteration to Article X. of Constitution	253
Brown, G. M.	The Transverse Framing of Ships	168
Browne, Sir B. C. ...	Address on Installation as President	257
Camps, H. E. J. ...	Some Considerations in Connection with the Transverse Framing of Ships ...	97
" ...	Reply to the Discussion on the Transverse Framing of Ships	191
Caws, F.	The Transverse Framing of Ships	165
De Rusett, E. W. ...	Comparison and Construction of Ships' Lines ...	22
" ...	Water Ballasting of Steamers	91
" ...	The Transverse Framing of Ships	163
" ...	The Designing of Cargo Steamers	183
Duncan, G. T.	Theory of the Centrifugal Pump and Fan	66
Dykes, G.	A Reliable Method of Obtaining the Necessary Displacement and Centre of Buoyancy of Ships	237
Fothergill, J. R. ...	Comparison and Construction of Ships' Lines ...	26
" ...	Gold Medal Awards	30
" ...	Water Ballasting of Steamers	84
" ...	Institution Dinner	127
" ...	Graduates' Awards	162
" ...	The Designing of Cargo Steamers	182, 185
" ...	Cylinder Ratios	225
" ...	Different Arrangements of Crank Angles	235
Gaine, R. L.	Cylinder Ratios	215
Gibson, J. H.	Cylinder Ratios	224
Griffith, E.	Different Arrangements of Crank Angles	251
Gurney, Principal ...	Institution Dinner	122
Heck, J. H.	Instrument for Gauging Boiler Furnaces	159
Hirst, R.	Water Ballasting of Steamers	90
Hogg, A.	Comparison and Construction of Ships' Lines	15
"	Reply to the Discussion on the Comparison and Construction of Ships' Lines	131
"	The Designing of Cargo Steamers	184
Hunter, G. B.	Comparison and Construction of Ships' Lines ...	24
Innes, C. H.	The Theory of the Centrifugal Pump and Fan	43
"	Reply to the Discussion on the Theory of the Centrifugal Pump and Fan	135

Name.	Name of Paper or Subject under Discussion.	Page.
Innes, C. H.	Cylinder Ratios	211
James, M. C.	Water Ballasting of Steamers	145
Jones, G.	Water Ballasting of Steamers	92
"	The Transverse Framing of Ships	119
King, J.	Comparison and Construction of Ships' Lines ...	33
"	Water Ballasting of Steamers	147
Long, A. E.	Comparison and Construction of Ships' Lines ...	40
"	Some Points of Interest in the Designing of Cargo Steamers	173
"	Reply to the Discussion on the Designing of Cargo Steamers	243
McGlashan, A. ...	Water Ballasting of Steamers	77
" ...	Reply to the Discussion on the Water Ballasting of Steamers...	93, 148
Mellanby, A. L. ...	Cylinder Ratios	217
" ..	The Effects of Different Arrangements of Crank Angles upon the Economy of Quadruple Expansion Engines	227
" ...	Reply to the Discussion on the Different Arrangements of Crank Angles	251
Messenger, T.	An Instrument for Gauging the Circularity of Boiler Furnaces and Cylinders and Producing a Diagram	155
Mudd, T.	Institution Dinner	124
Muir, A. E.	Water Ballasting of Steamers	91
Muir, R. H.	Water Ballasting of Steamers	141
Pollard, T.	Theory of Centrifugal Pump and Fan	135
Richardson, Sir Thomas, M.P.	Visit to the Hartlepool Engine Works	75
Russell, G.	Institution Dinner	124
Sanderson, T. B. (Mayor of Newcastle-upon-Tyne)	Institution Dinner	126
Sinton, J. K.	Different Arrangements of Crank Angles	234
Sivewright, G. W. ...	Water Ballasting of Steamers	87
Swan, Col. H. F. ...	President's Opening Remarks	12
" ...	Comparison and Construction of Ships' Lines ...	27
" ...	Visit to Hartlepool Works	75
" ...	Water Ballasting of Steamers	94, 154
" ...	Institution Dinner	123
" ...	Transverse Framing of Ships	171
" ...	Alterations to Constitution and Bye-Laws ...	253, 254
" ...	Installation of the New President	256
" ..	Reply to Vote of Thanks	259
Thompson, R.	Comparison and Construction of Ships' Lines ...	23, 36
"	Water Ballasting of Steamers	86
"	Transverse Framing of Ships	118
"	The Designing of Cargo Steamers	197
"	Vote of Thanks to Retiring President	258
"	On Attendance of Members	260
Thomson, James ...	Water Ballasting of Steamers	92
" ..	Vote of Thanks to Retiring Members of Council ...	260
Trechmann, O. K. ..	Water Ballasting of Steamers	88
Watson, T. H. ...	Transverse Framing of Ships	164
Weighton, R. L. ...	Comparison and Construction of Ships' Lines ...	37
" ...	Cylinder Ratios	219
" ...	Different Arrangements of Crank Angles	233–235
" ...	Vote of Thanks to Retiring President	259
White, R. Saxon ...	Comparison and Construction of Ships' Lines ...	25
Yeoman, F.	Water Ballasting of Steamers	89

BOOKS AND TRANSACTIONS OF LEARNED SOCIETIES ADDED TO THE LIBRARY.

BOOKS.

Castings and Founding. Sprelson.
Electrical Engineering. Slingo and Brooker.
Know your own Ship. Walton.
Fleming's Transformers, 2 vols.
Reed's Extra Engineer's Guide.
Thompson's Polyphase Electric Currents.
Lineham's Mechanical Engineering.
Hawkin's Dynamo.
Kemp's Yacht Building.
Donkin & Kennedy's Experiments on Steam Boilers.
Donkin's Heat Efficiency of Steam Boilers.
Marine Steam Engine. Sennet.
Notes of Steam Engines, Pumps, Boilers, etc. Morton.
Modern Locomotive Construction. Meyer.
Modern Locomotives.
Manual of Laying-off Vessels. Watson.
Reid's New Map of River Tyne.
Valves and Valve Gearing. Hurst.
Applied Mechanics. Perry.
Electric Motive Power. Snell.
Motive Power and Gearing for Electric Machinery. Carter.
Brassey's Manual.
Railway Construction. Mills.

TRANSACTIONS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Vol. XVIII., 1897.—Report of Progress of the Committee on Fire-proofing Tests. Progress in the Manufacture of Iron and Steel. President's Address, 1896. Some Special Forms of Computers. Experimental Investigations of the Cutting of Bevel Gears with Rotary Cutters. The Washing of Bituminous Coal by the Lührig Process. Paper Friction Wheels. Ancient Pompeiian Boilers. Method of Determining the Work Done Daily by a Refrigerating Plant, and its Cost. Calibration of a Worthington Water Meter. A Two-hundred-foot Gantry Crane. The "Promise and Potency" of High-pressure Steam. A Method of Determining Selling Price. Friction Horse-power in Factories. Rustless Coatings for Iron and Steel. Steam-engine Governors. The Moment of Resistance. Efficiency of the Boiler Grate. Contraction and Deformation of Iron Castings in Cooling from the Fluid to the Solid State. Aluminium-bronze Seamless Tubing. Historical and Technical Sketch of the Origin of the Bessemer Process. The Metric System *versus* the Duodecimal System. Volumnar Contraction of Castings in Cooling. New Form of Transmission Dynamometer.

The Best Load for the Compound Steam-engine. Adiabatics. Tests to Show the Influence of Moisture in Steam on the Economy of a Steam Turbine. The Effect of Alternative, Positive, and Negative Stresses on Iron and Steel. The Yield Point of Iron and Steel. On Rating Electric Power Plants upon the Heat-unit Standard. Current Practice in Engine Proportions. Diagrams for Relative Strength of Gear Teeth. Tests of Three Sulzer Engines. A Pocket Recorder for Tests of Materials. A Mirror Extensometer. Electricity *versus* Shafting in the Machine Shop. A Method of Shop Accounting to Determine Shop Cost and Minimum Selling Price. Flue Gas Analyses in Boiler Tests. Hygrometric Properties of Coals. The Laws of Cylinder Condensation. Experiments in Boiler Bracing. A Continuous Steam-engine Indicator. An Apparatus for Accurately Measuring Pressures of Ten Thousand Pounds per Square Inch and Over. Electric Power Equipment for General Factory Purposes.

AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. IX., 1897, No. 3.—Contract Trial of the U.S. Sea-going Battleship "Iowa." On Crank Shafts. Reconstructed American Motors. Contract Trial of the U.S. Gunboats "Vicksburg," "Newport," and "Annapolis." Rotary *versus* Reciprocating Marine Engine. Contract Trial of the U.S.S. "Nashville." Vol. X., 1898, No. 1.—Steam Consumption of the Main and Auxiliary Machinery of U.S.S. "Minneapolis." Propulsive Power. Central Power Plants on board Ships. Water-tube Boilers. Trials of the Niclausse Safety Water-tube Boiler. Boiler-testing with various Fuels. Speed of Construction. The Diesel Motor. Speed and Power Trials of a Light Draught Steam Launch.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Vol. X., 1896, Part 2.—Storage of Water in Earthen Reservoirs. Experiments in Concrete, made at McGill University. That Engineering Works shall be constructed by day's work instead of being done through a Contractor. A new and cheap method of Dressing Car Wheels, Axles, etc. Vol. XI., 1897, Part 2.—Fortifications. Experiments on White Pine, Red Pine, Hemlock and Spruce. Sewage Disposal by Subsoil Irrigation. Impulse Water Wheels.

CIVIL ENGINEERS, Vol. CXXIX., 1896-7, Part 3.—Cold Storage at the London and India Docks. Main Drainage of London. The Purification of the Thames. The Mond Gas-producer Plant and its Application. Inland Navigation of the United States. Economic Railway Construction in Victoria. St. Rollox Locomotive and Carriage Works of the Caledonian Railway. Horwich Locomotive Works of the Lancashire and Yorkshire Railway. Junee Waterworks, N.S.W. Action of Sea Water upon Hydraulic Cements. Fissures in Masonry Dams.

CLEVELAND INSTITUTION OF ENGINEERS, 1897-8, No. 1.—President's Address. Notes on Modern Practice in Electric Power Work—N.E. Coast. No. 2.—Principles and Elements of Electric Driving.

GENIO CIVILE, Vol. XXXV., 1897, Fas. 4, 5, and 6.—Papers on Civil Engineering. Fas. 11 and 12, 1897, and 1, 2, 3, 1898. Papers on Civil Engineering.

HULL INSTITUTION OF ENGINEERS, Vol. XI.—Inquiries, Tenders, Specifications, and Contracts. Siemens-Martin Mild Steel. Education of Engineers. Renewal of Marsh Lane Tunnel, Leeds. Ships' Cabins and their Fittings. Light or Narrow Gauge Railways.

INGÉNIEURS CIVILS DE FRANCE, Anno L., Nos. 6, 7, 8, and 9.—Papers on Civil Engineering. Annuaire, 1898.—Bulletin XII., 1897. Nos. 1, 2, and 3, 1898.

IRON AND STEEL INSTITUTE, No. 1, 1897.—On Microscopic Accessories for Metallographer. Weardale Furnace. On the Permeability of Steel-melting Crucibles. Charging Open-hearth Furnaces by Machinery. On the Practice of the Combined Open-hearth Process of M. Bertrand and Thiel on Malleable

Cast Iron. The Relation of Carbon to Iron at High Temperatures. On the Determination of Hardening Carbon and Carbide Carbon. On the General Utility and Economy of Central Blast Cupolas. Agricultural Value of Sulphate of Ammonia from Blast Furnaces. On the Specific Heat of Iron at High Temperature. Index, 1869–96, No. 2, 1897.—On the Application of Travelling Belts to the Shipment of Coal. On the Manufacture of Tin Plate. On Passive Iron. On the Diffusion of Sulphide through Steel. On Thermo-Chemical Study of the Refining of Iron. On Carbon and Iron. On a Portable Recorder for Tests of Metals. On a Spectrographic analysis of Iron Ores and Associated Minerals. On the Iron Industry of Hungary.

JUNIOR ENGINEERS, Vol. VI., 1895–6.—Belgian Electrical Engineering Practice. Notes on the Stability of Tall Chimneys. Coal Handling for Steam Generation. Dredgers. Gas Engines and Hot Air Motors. Urban Roads and Footways.

L'ASSOCIATION TECHNIQUE MARITIME, 1896, No. 7.—Papers on Engineering.

L'ASSOCIATION DES INGÉNIEURS DE LIEGE, Annuaire, Tome X., No. 2. Bulletin, Tome XXI., Nos. 3 and 4.—Papers on Engineering. Annuaire, Tome XI., No. 1. Bulletin, Tome XXII., No. 2.—Papers on Engineering.

LIVERPOOL ENGINEERING SOCIETY, Vol. XVIII., 1897.—Notes on Railway Construction. Water-tube Boilers. Notes on Current Specifications and Tenders for Public Works. Mechanical Refrigeration. Electric Tramways. Principals of the Law of Rating as affecting Engineering Works. Dock Gates. A Description of the Construction of Cold Stores for the Preservation of Perishable Human Food. Sewage Sludge Removal and Shipment. Silting of Small Harbours and the Effect of a Stream of Water.

MANCHESTER ASSOCIATION OF ENGINEERS, 1897.—Efficiency of Steam Boilers. Transmission of Heat through Surfaces. Motor Vehicles for Roads. High Speed Engine for Mill Driving. Patents and Patent Law. Roller Bearings and their Application. Hydraulic Plant for Compressing Air.

MARINE ENGINEERS, Vol. VIII., 1896–7.—Liquid Fuel. Engineers and the R.N.R. White Metal for Bearings. Water-tube Boilers. Boiler Scale and Incrustation. Bearings of Marine Engines. Electric Welding. Assistant Cylinder for Valve Gears.

MECHANICAL ENGINEERS, 1896, No. 3.—Flax Scutching and Flax Hackling Machinery. Electric Lighting in Belfast. Unusual Corrosion of Marine Machinery. Rope Driving. Alumina Factory at Larne Harbour. Belfast Gas Works. 1897, Parts 1 and 2 (bound).—Alloys Research. Partially Immersed Propellers. Canoe Boat Propulsion.

NAVAL ARCHITECTS, Vol. XXXVIII., 1897.—The Maritime Position and Principal Features of the Port of Hamburg. Shipbuilding in Germany. Recent Improvements in Docking and Docking Appliances. Development in Design and Construction of German Men-of-War. Classification and Relative Power of Warships. Signs of Weakness in Tank Steamers. Various Descriptions of Doors Applicable to Watertight Bulkheads, their Fastenings, etc. Use of Electricity on Board Ships.

NAVAL ARCHITECTS AND MARINE ENGINEERS, 1897.—Watertight Bulkhead Doors. Regulations for Loading Vessels. Torpedo Boat Design. Commerce of the Great Lakes. Progressive Trials of the "Guardian." An Experimental Study of the Influence of Surfaces upon the Performances of Screw-propeller. Some Notes on Speed Trials and Experiences in connection with our New Battle Ships. Use of Water Ballast. Estimated Weights of Machinery. Navy Yard Expenses. Pneumatic Steering Gear.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, Vol. XLVI., 1896–7.—Further Experiments with Explosives. The Danger of Employing Safety Fuzes for Blasting in Fiery Mines. A Spring Coupling for Winding or Hauling Ropes. Note on the Venterskroom Gold-fields. The Gold-fields of the Hauraki Peninsula, New Zealand. The Education of Metallurgists. Notes upon Gold-mining in Burma. Note on the Tellurium Mineral of Choukpazat. Notes on Coal-mining. Eccentric Haulage Clip. Honigmann System of Boring and Sinking Shafts. Notes upon Foreign Mining Laws. The Coal Industry of the South-Eastern States of North America. Notes on the Sinking of Two Shafts at Clara Vale. Cornish Methods of Mine Timbering. Shaw Gas-tester. The Mineral Resources of Queensland. Notes on the Coal Seams of the Transvaal. Economical Combustion of Coal for Steam-raising Purposes. Also Borings and Sinkings (Vol. VI.).

NOVA SCOTIA INSTITUTE OF SCIENCE, Vol. IX., 1896–7, Part 3.—On the Relation of the Physical Properties of Aqueous Solutions to their State of Ionization. On Some Analyses of Nova Scotia Coal and other Minerals. Notes on Nova Scotia Zoology. Phenological Observations, Canada, 1896. Note on Venus. Rainfall in 1896. Report of the Court of Enquiry on the Destruction of the U.S.S. "Maine," 1898.

PHILOSOPHICAL SOCIETY OF GLASGOW, 1896–7.—Art in our City. Pollution of Scotch Rivers. The Literary Art of Robert Burns. Some Aspects of Political Economy. Educational Experiments. The Andersonian: A Centenary Sketch. House Sanitation. Sugar Bounties. Sound and Speech Waves as revealed by the Phonograph. The Vaccination Commissioners' Report. The Law of Mutual or rather Common Gables. X Rays. The Mechanical Propulsion of Tramway Cars.

SOCIETY OF ENGINEERS, 1897.—Notes on Bye-Laws on Drainage. Rating of Engineering Undertakings. Automatic Gas Station Governors. Compression of Air by the Action of Water. Filter Presses for Sewage Sludge. Sea Defences. Pollution of Water.

SOUTH WALES INSTITUTE OF ENGINEERS, Vol. XX., 1897, No. 5.—Subsidence caused by the Working in Mines. Cost of Secondary Horse Haulage. Vol. XX., 1898, No. 7.—Improvements in Safety Explosives. Haulage and Sinking.

U.S. NAVAL INSTITUTE, Vol. XXIII., 1897, No. 2.—Proposed Uniform Course of Instruction for the Naval Militia. Composition and Arrangement of Ships' Batteries. The Yacht "Defender." The Perforation of Face-hardened Armour. Military Training. No. 3.—Torpedoes in Exercise and Battle. Washington's Forgotten Maxim. The Consolidated Mess of the Crew of the U.S.S. "Indiana." The Sailor in the "Resolution." Development of Smokeless Powder. Naval Policy of America. Yacht "Defender." No. 4.—Homing Pigeons. Pyro-Collodion Smokeless Powder. The Olny Device for Torpedoes. Search Curves. Naval War College. Mechanism of Modern Naval War. Notes on the Literature of Explosives. Vol. XXIV., 1898, No. 1.—Development of Smokeless Powder. Naval Power. Whitehead Torpedo. Battleships.

WESTERN SOCIETY OF ENGINEERS, Vol. II., 1897, No. 3.—Railway Ties in India. The Bretts Landing Cable, Hoist, and Quarry. Rope Transmission. Concrete Water-power Dam at Rock Island Arsenal (Illustrated). No. 4.—Limestone Screenings in Cement Mortar. Ironwork in the Old Post Office and Custom House Building in Chicago. Variable Efficiency of Steam Boilers and their Influence on tests. The Internal Hydrostatic Pressure in Masonry, with especial reference to Masonry Dams. No. 6.—Drainage Canal. Regulation of the Water Supply at Savannah. Testing Cement. Vol. III., 1898, No. 1.—Some Engineering Features of the Nicaragua Canal. Smith Works of the Illinois Steel Company. A Glacial Lake.

PUBLICATIONS RECEIVED TO DATE, CURRENT NUMBERS OF WHICH LIE ON THE TABLES OF THE READING ROOM:—

Cassier's Magazine, 33, Bedford Street, Strand, London, W.C.
Electrical Engineer, 139, Salisbury Court, Fleet Street, London, E.C.
Electrical Review, 22, Paternoster Row, London, E.C.
Engineering, 35 and 36, Bedford Street, Strand, London, W.C.
Engineers' Gazette, Prudential Buildings, Mosley Street, Newcastle-upon-Tyne.
Fairplay, 34, Leadenhall Street, London, E.C.
Indian and Eastern Engineer, 50, Fenchurch Street, London, E.C.
Indian Engineering, Pat. Doyle, Esq., C.E., Star Press, 19, Lall Bazar, Calcutta, British India.
Industries and Iron, 39 and 40, Shoe Lane, London, E.C.
Journal de la Marine le Yacht, 55, Rue de Châteaudun, Paris.
Marine Engineer, 3, Amen Corner, Paternoster Row, London, E.C.
Mechanical World, New Bridge Street, Manchester.
Rivista Marittima, Rome.
Shipping World, Effingham House, Arundel Street, London, E.C.
Stahl und Eisen, Düsseldorf.
Syren, 126, Hope Street, Glasgow.
The Colliery Guardian, 49, Essex Street, Strand, London, W.C.
The Steamship, 2, Custom House Chambers, Leith.
The Electrician, 1, Salisbury Court, Fleet Street, London, E.C.
The Engineer, 33, Norfolk Street, Strand, London, W.C.
The Engineering Magazine, 222, Strand, London, W.C.
The Mariner, 22, Buckingham Street, Strand, London, W.
The Mechanical Engineer, Hodson's Court, Corporation Street, Manchester.
The Practical Engineer, 31, Whitworth Street, Manchester.
Transport, 28, Victoria Street, London, S.W.

BOUND COPIES OF THE TRANSACTIONS ARE PRESENTED TO THE FOLLOWING LIBRARIES:—

The British Museum, London.
Literary and Philosophical Society, Newcastle-upon-Tyne.
The Free Libraries of Newcastle-upon-Tyne, Gateshead, South Shields, Sunderland, and West Hartlepool.
The Bodleian Library, Oxford.
The University Library, Cambridge.
The Advocates' Library, Edinburgh.
Library of Trinity College, Dublin.
} G. W. Eccles, 96, Great Russell Street, London, W.C.
Patent Office Library, 25, Southampton Buildings, Chancery Lane, London.
Subscription Literary Society, Fawcett Street, Sunderland.
[illegible] College of Science, Barras Bridge, Newcastle-upon-Tyne.
[illegible]ford College, Bath Lane, Newcastle-upon-Tyne.

LIST OF OFFICERS.

FOURTEENTH SESSION, 1897-98.

President:—Col. HENRY F. SWAN, J.P.

Past-Presidents:

WILLIAM BOYD, J.P. (1884-86).
W. THEO. DOXFORD, M.P. (1886-88).
F. C. MARSHALL, J.P. (1888-90).
WIGHAM RICHARDSON, J.P. (1890-92).
ROBERT THOMPSON, J.P. (1892-94).
Sir THOMAS RICHARDSON, B.A., M.P. (1894-96).

Vice-Presidents:

Edwin W. De Rusett.
J. R. Fothergill.
Henry Fownes.
John Gravell.
Sir William Gray, J.P.
D. B. Morison.
James Patterson.
Joseph M. Rennoldson.
R. L. Weighton, M.A.

Honorary Treasurer:—G. E. Macarthy.

Councilmen:

Robert P. Doxford.
W. H. Dugdale.
Col. T. English.
J. B. Furneaux.
John H. Heck.
Summers Hunter.
M. C. James.
Robert Home Muir.
P. Phorson.
Robert Readhead.
Charles Rennoldson.
M. Sandison.
W. G. Spence.
John Walker.
Robert Wallis.

Assistant Librarian:—H. S. Wallace.

Secretary and Treasurer:—John Duckitt.

Graduate Section:

Chairman—Charles W. Cairns.

Hon. Secretary—Bryce G. Nichol.

Committee:

John Bowden.
Alfred H. Burbidge.
Robert Hinchliffe.
B. T. Lace.
William Lumley.

Offices, Library, and Lecture Room:

4, St. Nicholas' Buildings West, Newcastle-upon-Tyne.

COMMITTEES.

FOURTEENTH SESSION, 1897–98.

The President is *ex-officio* a Member of all Committees.

Finance Committee:

WILLIAM BOYD (Chairman).

E. W. DE RUSETT.
W. H. DUGDALE.
J. R. FOTHERGILL.
J. M. RENNOLDSON.
ROBERT THOMPSON.
GEORGE E. MACARTHY (Hon. Treasurer).

Reading Committee:

E. W. DE RUSETT.
W. H. DUGDALE.
J. R. FOTHERGILL.
J. H. HECK.
R. H. MUIR.
ROBERT WALLIS.

Library Committee:

W. G. SPENCE (Chairman).

M. C. JAMES.
P. PHORSON.
A. G. SCHAEFFER.
JAMES THOMSON.

Graduates' Award Committee:

HENRY FOWNES.
J. H. HECK.
M. C. JAMES.
M. SANDISON.
R. L. WEIGHTON, M.A.

Representatives on Lloyd's Sub-Committee:

WILLIAM BOYD.
F. C. MARSHALL.
ROBERT THOMPSON.
HENRY WITHY.

Representatives on the Consultative Committee to the Board of Trade:

J. H. IRWIN.
D. B. MORISON.
COL. JOHN PRICE.
COL. HENRY F. SWAN.

Representative on Council of Durham College of Science:

JOHN GRAVELL.

Representatives on Sub-Committee of Northumberland County Technical Education Committee:

SUMMERS HUNTER.
GEORGE E. MACARTHY.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1898.

EXPLANATION.

(A.)	Agent and Accountant.	(I. & S. M.)	Iron and Steel Merchants and Manufacturers.
(B. B.)	Boiler Builder.	(M.)	Merchant.
(C. E.)	Civil and Consulting Engineer.	(M. S.)	Marine Superintendent.
(E.)	Engineer and Boilermaker.	(N. A.)	Naval Architect.
(E. A.)	Engineering Agent.	(R. M.)	Rope Manufacturer.
(E. E.)	Electrical Engineer.	(S.)	Shipbuilder.
(F. M.)	Forge Master.	(S. O.)	Ship Owner.
		(SUR.)	Engineer & Ship Surveyor.

HONORARY MEMBERS.

		ELECTED.
The Right Honourable Lord Armstrong, C.B., D.C.L., F.R.S., Cragside, Rothbury		Nov. 1884
The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead-on-Tyne...		Nov. 1884
Sir W. H. White, K.C.B., LL.D., F.R.S., The Admiralty, Whitehall, London	(N A)	Nov. 1884
The Right Honourable the Earl of Hopetoun, G.C.M.G.. Hopetoun House, South Queensferry, N.B....		Nov. 1897

MEMBERS.

A.

Abey, Henry, Fairfield, York Road, West Hartlepool	(E)	Jan. 1889
Adams, Cecil T., 196, Holland Road, Kensington, London, W.	(E)	Graduate, Oct. 1891 Member, Nov. 1897
Adams, Dawson, c/o Messrs. The National Electric Supply Co., Ltd., Bushell Street, Preston, Lancashire	(E E)	Graduate, Oct. 1894 Member, Dec. 1897
Adamson, Alex., c/o Messrs. Vickers, Sons & Co., Naval Construction Works, Barrow-in-Furness...	(S)	Nov. 1885
Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde, Cheshire	(E)	Graduate, Feb. 1888 Member, Oct. 1894
Adamson, James Young, 34, Albert Street, Barrow-in-Furness	(S)	Nov. 1896
Aisbitt, Matthew Wheldon, 47, Mount Stuart Square, Cardiff ...	(N A)	Oct. 1895
Alder, Sydney, Edinbro' Buildings, South Shields	(C E & N A)	Nov. 1893
Alexander, Francis H., 42, Percy Park, Tynemouth	(S)	May 1898
Allan, Jas. McNeal, The Poplars, Monkseaton, Northumberland...	(E)	Dec. 1886
Allardes, Wm., c/o Messrs. Harland & Wolff, Ltd., Engine Works, Belfast	(E)	Nov. 1884

ELECTED.

Anderson, Joseph, Westfield Terrace, Wallsend-on-Tyne ... ... (E) Nov. 1884
Anderson, Thos. James, 2118, Strand, Galveston, Texas, United States of America ... ... (E SUR) Mar. 1898
Andrew, D., 33, Osborne Road, Jesmond, Newcastle-upon-Tyne ...(SUR) Jan. 1885
Andrews, Jas., Mid Eton. Cathcart, Glasgow ... ... (E) Nov. 1884
Angus, W. J., Messrs. Vickers, Sons & Co., Naval Construction Works, Barrow-in-Furness ... ... (E) Oct. 1892
Archbold, Joseph G., c/o Messrs. Blyth Dry Dock Co., Blyth ... (E) Jan. 1889
Armour, Jas. Glencairn, Cereal Court A, Brunswick Street, Liverpool ... ...(SUR) Oct. 1895
Armstrong, Joseph, 96, Roker Avenue, Sunderland... ... ... (S) Nov. 1892
Armstrong, Robert B., c/o Messrs. Day, Summers & Co., Northam Ironworks, Southampton ... ... (E) Oct. 1887
Arnison, Geo., 61, Fawcett Street, Sunderland ... (N A & SUR) Nov. 1884
Atherton, William Henry, B.Sc., 43, Upper Brook Street, Manchester (E) Oct. 1891
Atkinson, F. C., 37, Croydon Road, Newcastle-upon-Tyne... ... (E) Dec. 1892
Atkinson, John Joseph, 7, Swiss Road, Elm Park, Fairfield, Liverpool ... ... (E) Mar. 1891
Austin, W. R., Lloyd's Register of Shipping, 342, Argyle Street, Glasgow ... ... (E SUR) Oct. 1888

B.

Bagnall, T. W., The Groves, Winlaton ... ...(F M) Nov. 1893
Baguley, Ernest Edwin, The Cottage, Dunston, Penkridge, Staffordshire ... . (E) April 1891
Bailey, Charles H., Tyne Engine Works, Newport ... ... (E) Mar. 1896
Bailey, James, 3, South Avenue, Ryton-on-Tyne ... ... (E) Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool ... ... (E) Oct. 1888
Baird, George, 25, Newcastle Road, North Shields ... ... (E) Oct. 1892
Baird, Robert, 13, Hylton Terrace, North Shields ... ... (E) Jan. 1890
Baker, E. F., H.M.S. "Majestic," Channel Squadron (E) { Graduate, Nov. 1892; Member, Feb. 1898 }
Barclay, James, Lloyd's Register of Shipping, Swansea ... ...(SUR) Nov. 1888
Barley, C. J., c/o Messrs. The Kensington and Knightsbridge Electric Lighting Co., Chapel Place, Brompton Road, London, S.W. ... ... (E) { Graduate, Feb. 1885; Member, Dec. 1886 }
Barnett, James Rennie, Lilybank House, Johnston, N.B.... ... (S) Oct. 1889
Barnsley, John, Field House West, North Shields ... ... (E) May 1892
Barrett, A., Staith House, West Hartlepool ... ... (E) May 1896
Barron, T. G., Hobourne, Elwick Road, West Hartlepool... ... (E) Oct. 1888
Barrow, A. R., Holly Grove, Fittleworth, near Pulbrough, Sussex (E) Feb. 1891
Batey, John Thomas, 25, Harrison Place, Newcastle-upon-Tyne ... (S) Nov. 1885
Batliboi, Jehangir Framji, 71, Apollo Street, Fort, Bombay ... (E) Dec. 1888
Baxter, J., 26, Simonside Terrace, Heaton, Newcastle-upon-Tyne (E) Nov. 1884
Beadon, D. C., "Stoneham," Beech Grove Road, Newcastle-upon-Tyne... ... ... (E) Jan. 1885
Bell, Geo. Arthur, 48, Crown Street, Newcastle-upon-Tyne (E) { Graduate, Oct. 1890; Member, Jan. 1894 }
Bell, William, Messrs. Cleland's Slipway Co., Willington Quay-on-Tyne ... . (E) Nov. 1888

ELECTED.

Berkley, A. B., Kent Villas, Jarrow-on-Tyne ... ... (E) Mar. 1887
Bigge, D. L. Selby, 27, Mosley Street, Newcastle-upon-Tyne ... (E E) Nov. 1894
Billetop, Torben Christian, 3, Guildford Place, Heaton, Newcastle-upon-Tyne ... ... (E) Nov. 1896
Bindesböll, S. C. W., Helsingors Lernskibs Cygerrie, Denmark ... (S) Nov. 1884
Black, J., 1, Church Street, West Hartlepool ... ... (E) Nov. 1888
Black, Wm., 1, Lovaine Place, Newcastle-upon-Tyne ... ... (E) Jan. 1885
Blackett, Walter, 19, Valleytost Road, Stoke, Devonport ... ... (E) { Graduate, Nov. 1886; Member, Nov. 1892 }
Blackie, Thomas Reid, Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London ... ... (SUR) Nov. 1890
Blenkinsop, John N., Marine Supt. Engineer, Great-Eastern Railway, Parkeston Quay ... ... (E) Oct. 1885
Blomberg, Carl A., 2262, North 19th Street, Philadelphia, Pa., United States of America ... ... (E) Oct. 1896
Blumer, Wm., Woodside, Sunderland... ... ... (S) Dec. 1886
Boddy, John, 96, Dock Street, Newport, Monmouthshire ... ... (E) Dec. 1888
Bodin, Lauritz M., 27, Argyle Square, Sunderland... ... (E & SUR) Dec. 1889
Bone, W. J., 61, Linskill Terrace, North Shields ... ... (S) Dec. 1884
Bonnyman, James Smith, 64, Plasturton Avenue, Cardiff... ... (E) Nov. 1889
Boolds, Jas. H., Woodlands Road, Middlesbrough .. .. (S) Oct. 1886
Booth, Edward Spence, Box 5124, Boston, U.S. America ... (M S & N A) Oct. 1889
Booth, John William, Union Foundry, Rodley, near Leeds ... (E) April 1892
Bosi, Guiseppe, Presso Rastelli, Sampierdarena, Genoa, Italy (E & NA) Jan. 1894
Boulton, Thomas, 33, Broad Chare, Newcastle-upon-Tyne ... (E) Dec. 1896
Boyd, Arthur, Lloyd's Register of Shipping, Bute Docks, Cardiff (E SUR) May 1895
Boyd, Wm., North House, Long Benton, Newcastle-upon-Tyne ... (E) Nov. 1884
Boyt, John T., Messrs. Earn Line Steamship Co., Girard Building, Philadelphia, Pa., U.S.A.... ... ... (E) Nov. 1893
Bramwell, Balfour, c/o Messrs. Harland & Wolff, Engine Works, Belfast ... ... (E) { Graduate, Nov. 1886; Member, Nov. 1887 }
Brankston, R. T., 36, Hawthorn Street, Newcastle-upon-Tyne ... (E) Nov. 1884
Brash, James, 2, Bolton Terrace, Newcastle-upon-Tyne ... ... (E E) Nov. 1897
Brew, George, 44, Francois, Xavier Street, Montreal (SUR & C E) May 1896
Brigham, Robert F., 72, Linskill Terrace, North Shields ... ... (E) Mar. 1897
Broadbent, Frank, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-upon-Tyne ... ... (E E) Nov. 1893
Brotherstone, James, 2, Salisbury Street, Sunderland ... ... (E) Oct. 1895
Brown, Eugene, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-upon-Tyne ... ... (E E) Feb. 1886
Brown, Geo. Matthew, Birk Heads, Marley Hill, Swalwell, R.S.O. ... ... (E) { Graduate, April 1895; Member, Nov. 1897 }
Brown, James, c/o Sociedad Anonima, de los Astilleros del Nervion, Bilbao, Spain ... ... (E) Mar. 1891
Brown, Robson, 32, Salmon Street, South Shields ... ... (E) Nov. 1889
Brown, T. R., 27, Ripon Street, Sunderland ... ... (E) { Graduate, May 1885; Member, Oct. 1886 }
Brown, William, c/o Messrs. Siemens Brothers & Co., Woolwich... (E) April 1887
Browne, Sir B. C., Westacres, Benwell, near Newcastle-upon-Tyne ... ... (C E) Jan. 1885
Buchanan, A., Michaelson Villa, Barrow-in-Furness ... ... (S) Nov. 1884

ELECTED.

Buchanan, John H., Oswald Chambers, 5, Oswald Street, Glasgow (SUR) Oct. 1888
Buckland, H. B., Baltic Chambers, Quayside, Newcastle-upon-Tyne (E) Nov. 1885
Buckwell, George William, Board of Trade Surveyor's Offices, Custom House Arcade, Liverpool ... ...(SUR) Oct. 1896
Bull, John Catharinus, 29, Bexley Heath, Erith, Kent ... ... (E) Oct. 1892
Bulmer, Frederick Charles, 2, Graingerville North, Newcastle-upon-Tyne ... ... (E) { Graduate, May 1894; Member, Oct. 1895 }
Bulmer, John, 1, Graingerville North, Newcastle-upon-Tyne ... (E) Mar. 1886
Bulmer, John George, 34, Brighton Grove, Newcastle-upon-Tyne (E) May 1894
Burnett, Norman, Watergate Buildings, Newcastle-upon-Tyne ... (E) Oct. 1891
Bush, Montague, c/o Messrs. Ernest Scott, Mountain, & Co., Close Works, Newcastle-upon-Tyne ... ... (EE) Nov. 1896
Bushell, Chas. A., 1, Benton Terrace, Newcastle-upon-Tyne (N A & SUR) Nov. 1893
Butterfield, George, 4, Kayll Road, Sunderland ... ... (S) Nov. 1884

C.

Cadman, C. C., Clifton Holm, York ... ... (E) { Graduate, Nov. 1891; Member, Dec. 1897 }
Cairns, C. W., Cheriton House, Lothian Road, West Hartlepool ... ... (E) { Graduate, Nov. 1894; Member, Dec. 1897 }
Cama, Nusserwanji Bomanji, Sleater Road, Tardeo, Bombay, British India ... ... (E) Dec. 1888
Cameron, Angus, c/o James Laing, Esq., Deptford Yard, Sunderland (S) Nov. 1892
Campbell, J. Jennings, Bureau Veritas Register of Shipping, 155, Fenchurch Street, London, E.C. ... ... (E) Oct. 1888
Campbell, John M., 4, Winchester Terrace, Newcastle-upon-Tyne (N A) April 1895
Campbell, Thomas, c/o Messrs. Hills Dry Dock Co., Cardiff ... (S) Mar. 1894
Camps, H. E. J., The Limes, Long Benton, Newcastle-upon-Tyne (S) Oct. 1894
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Carney, J. H., Glengariffe, Stow Park, Newport, Monmouth ... (E) Mar. 1897
Carruthers, Frank, 9, Battlefield Gardens, Langside, Glasgow ... (E) Nov. 1893
Carstons, Samuel, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark... ... ... (S) Dec. 1887
Carter, Geo. J., Elswick Shipyard, Newcastle-upon-Tyne... ... (N A) Dec. 1897
Casey, James, 10, Philpot Lane, London, E.C. ... ... (E) Nov. 1891
Ceuvel, John L., 86, Prins Hendrikkade, Amsterdam ... ... (E) Mar. 1886
Chandler, Noel, Messrs. Bumsted & Chandler, Cannock Chase Engine Works, Hednesford, Staffordshire ... ... (E) Oct. 1891
Chapman, Harry Reynolds, Messrs. Clarke, Chapman, & Co., Gateshead-on-Tyne ... ... (E) Mar. 1893
Charlton, Henry, 1, Millfield Terrace, Gateshead-on-Tyne ... (E) Nov. 1884
Charlton, R. B., Jun., Manors Railway Station Works, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Charlton, T., 25, Lincoln Street, Gateshead-on-Tyne ... ... (E) Nov. 1884
Charlton, Thomas, The Cedars, Millhill, West Cowes, Isle of Wight (E) Nov. 1890
Chaston, Edward Catmore, 27, Larkspur Terrace, Newcastle-upon-Tyne ... ... (E) Oct. 1894
Cherry, Thos. Wm. Fry, c/o Messrs. The Greenock Foundry Co., Greenock ... ... (E) Oct. 1894
Chicken, Thomas, c/o Messrs. Newport Engineering and Ship Repairing Co., Newport, Monmouth ... ... (E) Oct. 1892

ELECTED.

Chisholm, Alexander, 92, George Road, Wallsend-on-Tyne ... (S) Mar. 1893
Christie, C. J. D., Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Christie, J. D., Woodside, Tynemouth ... ... (S) Nov. 1884
Christie, Reginald, Woodside, Tynemouth ... ... (E E)
Churchill, James Dixon, 9, London Street, London, E.C.... ... (E) Oct. 1889
Clague, James Henry, Birkenhead Ironworks, Birkenhead ... ... (S) { Graduate, April 1891 / Member, May 1894
Clark, Charles, c/o Messrs. Robert Irvine & Co., Tower Chambers, West Hartlepool ... ... (E) Jan. 1897
Clark, Geo., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884
Clark, George, Jun., Southwick Engine Works, Sunderland ... (E) Feb. 1888
Clark, Henry, Southwick Engine Works, Sunderland ... ... (E) Oct. 1887
Clarke, Harry, 23, West Parade, Newcastle-upon-Tyne ... ... (E) Mar. 1897
Clarke, Henry Trevisa, Deptford Shipyard, Deptford, Sunderland (S) Mar. 1892
Clarke, William Henry, The Hermitage, Gateshead-on-Tyne ... (E) Dec. 1896
Cleghorn, Alexander, Datcha, Scotstounhill, near Glasgow ... (E) Feb. 1897
Coates, Matthew C., 26, Denmark Street, Gateshead-on-Tyne ... (E) Nov. 1897
Cohn, William M., 2, Marine Terrace, North Shields ... ... (S) Nov. 1893
Coleby, James W., 42, Burns Terrace, Willington Quay-on-Tyne ... ... (E) { Graduate, Oct. 1891 / Member, Jan. 1894
Coletti, Silvio, 83, Park Road, Newcastle-upon-Tyne ... ... (S) Dec. 1895
Common, John B. A., 51, Mount Stuart Square, Docks, Cardiff ... (E) April 1896
Conràdi, Carl, 8, Toldbodgaden, Christiana, Norway ... ... (E) Nov. 1884
Consiglio, Luigi, 8, Via Paterno, Palermo ... ... (N A) Nov. 1890
Cookson, John A., 2, St. Edmund's Road, Gateshead-on-Tyne ... ... (E) { Graduate, Dec. 1895 / Member, Nov. 1897
Cooper, Nusserwanji Naoroji, Indo-China Mills, Dader, Sivri, Bombay, India ... ... (E) Oct. 1889
Cooper, Sidney ... ... (E) { Graduate, Nov., 1891 / Member, May, 1895
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Copeman, William C. J., Clifton House, 1, Grosvenor Road, Ilford, Essex ... ... (E) Oct. 1892
Cornish, H. P., Lloyd's Register of Shipping, Hull ... ... (E) Oct. 1888
Couche, Henry Drew, c/o Messrs. Laird Bros., Birkenhead ... (S) Oct. 1891
Coull, Alex. B., Baltic Chambers, Newcastle-upon-Tyne ... ... (C E) Jan. 1898
Courtier-Dutton, W. T., British Corporation Registry of Shipping, 69, St. Vincent Street, Glasgow... ... ... (S SUR) April 1890
Cowan, Robert, 14, Osborne Avenue, South Shields ... ... (E) Dec. 1896
Cowens, William Edward, c/o Messrs. John Abbot & Co., Gateshead-on-Tyne ... ... (E) Dec. 1889
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesbrough ... (S) Oct. 1888
Craig, Robert, Pageland House, Grange Road, West Hartlepool ... (E) Nov. 1892
Crawford, Jas., Bureau Veritas Register of Shipping, 9, Custom House Court, Quayside, Newcastle-upon-Tyne ... (S SUR) Nov. 1886
Crawford, William, 60, Holly Avenue, Newcastle-upon-Tyne ... (E) Dec. 1896
Crofton, Charles, 17, Albany Terrace, Whitley, near Newcastle-upon-Tyne ... ... (E) Nov. 1895
Crookston, John, 72, Mark Lane, London, S.E. ... ... (E) Mar. 1896
Cruddas, W. D., M.P., Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd., Elswick, Newcastle-upon-Tyne ... ... (E) Dec. 1884

ELECTED.

Cruickshank, Alexander, The Admiralty, Albany Buildings, 47, Victoria Street, London, S.W. ... ...(SUR) Mar. 1892
Cumming, Alexander, 20, Lorne Terrace, Sunderland ... ... (E) Nov. 1891
Cumming, William, c/o Mrs. Archer, Beach House, Broughty Ferry, N.B. ... ... (E) Mar. 1896
Cummins, W. R., Belle Vue, Wormit, Fife ... ... (E) Nov. 1884
Cunliffe, Tom Arthur, 12, Cresswell Terrace, Sunderland ... ... (E) Feb. 1897

D.

Dale, John, 26, Whitehall Terrace, Hylton Road, Sunderland ... (E) Mar. 1897
Dalrymple, Wm., Myrtle Cottage, W. Cleadon, Sunderland ... (E) Dec. 1886
Dalrymple, William, Jun., 8, Amberley Terrace, Sunderland ... (E) Dec. 1895
Daniel, Alfred John, Board of Trade Surveyors' Office, West Hartlepool ... ... (S) Nov. 1893
Darling, W. J., Lloyd's Register of Shipping, Dock Chambers, Barry ... ... (S) April 1887
Darney, John, c/o Messrs. Short Bros., Pallion, Sunderland ... (S) Nov. 1884
Davis, Thos. Wilfrid, Birkenfeld, Bromley, Kent ... (E) { Graduate, Jan. 1891 / Member, Mar. 1894
Davy, William. Greenfield Terrace, Ryton-on-Tyne ... ... (E) Oct. 1896
Dawson, Herbert, 5, Selborne Terrace, Gateshead-on-Tyne ... (E E) Nov. 1897
Deighton, William, Messrs. Deighton's Patent Flue Co., Vulcan Works, Pepper Road, Leeds ... ... (E) Nov. 1897
Denny, Archibald, c/o Messrs. W. Denny & Bros., Dumbarton ... (S) Dec. 1891
De Rusett, Edwin W., Warden House, Percy Park Road, Tynemouth ... ... (S) Nov. 1890
Dick, F. W., c/o Messrs. Palmer's Shipbuilding Co., Jarrow-on-Tyne... ... ... (I & S M) Oct. 1891
Dickie, James, 428, Mississippi Street, Potrero, San Francisco, California, U.S.A.... ... ... (S) Mar. 1894
Dickinson, F. T., 23, Park Place W., Sunderland ... (E) { Graduate, May 1885 / Member, Oct. 1886
Dickinson, James, The Cloisters, Sunderland ... ... (E) Nov. 1884
Dickinson, John, Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, W., Park House, Sunderland ... ... (E) Nov. 1884
Dietze, F. G., Messrs. The Hamburg South American Steam Ship Company, Hamburg ... ... (E) Nov. 1893
Dixon, James, c/o Messrs. Ropner & Sons, Shipbuilders, Stockton-on-Tees ... ... (S) Dec. 1893
Dixon, John Rochester, 79, Osborne Road, Newcastle-upon-Tyne ... ... (E) { Graduate, Oct. 1887 / Member, Feb. 1893
Dixon, Sir Raylton, Cleveland Shipyard, Middlesbrough ... ... (S) Feb. 1888
Dixon, William, Heaton Hall Road, Heaton, Newcastle-upon-Tyne (E) Nov. 1893
Dixon-Brown, L. D., 42, Burdon Terrace, Newcastle-upon-Tyne ... (S) Nov. 1886
Dobson, Henry James, c/o Messrs. William Dobson & Co., Newcastle-upon-Tyne ... ... (S) { Graduate, Oct. 1891 / Member, Feb. 1898
Dobson, William, Shipbuilder, Walker-on-Tyne ... ... (S) Nov. 1888
Donald, James, 58, General Gordon Terrace, Sunderland ... ... (S) Nov. 1884
Donkin, George, St. Andrew's Engine Works, Newcastle-upon-Tyne (E) Oct. 1892
Donovan, J. W., 5, Ash Place, Newcastle Road, Sunderland ... (E) April 1885

ELECTED.

Dos Santos, Apolinaris J., Rio Grande-do-Sul, Brazil ... (SUR) Nov. 1891
Douglas, John F., c/o Messrs. Ramage & Ferguson, Leith... ... (E) Jan. 1888
Dove, Herbert J., 25, Ashfield Terrace W., Newcastle-upon-Tyne (E) Nov. 1896
Downing, Nicholas, Glenbrooke, Victoria Avenue, Norton Road, Stockton-on-Tees ... ... (I F) Oct. 1894
Dowsen, Chas., 21, Croft Terrace, Jarrow-on-Tyne... ... ... (E) Dec. 1885
Doxford, Albert Ernest, M.A., 1, Grange Crescent, Sunderland... ... ... (E) { Graduate, Oct. 1890 / Member, Nov. 1893
Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland (S) Nov. 1884
Doxford, Robert P., Pallion Engine Works, Sunderland ... ... (E) Nov. 1884
Doxford, W. Theodore, M.P., Pallion Shipyard, Sunderland ... (S) Nov. 1884
Duckitt, Jno., Leazes Gate Villa, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Duckitt, John Brentnall, George Lane, Woodley, *via* Stockport, Cheshire... ... ... (E E) { Graduate, Oct. 1888 / Member, April 1895
Dudgeon, F. S., 30, Great St. Helens, London, E.C. ... ... (E) Feb. 1885
Dugdale, William H., Green Bank, Jarrow-on-Tyne ... ... (S) Mar. 1894
Duguid, Robert, c/o Messrs. Harland & Wolff, Drawing Office Department, Belfast ... ... (S) Oct. 1892
Duncan, George Thos., c/o Messrs. Tangyes Limited, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E) Nov. 1894
Dunlop, John, 65, Sydenham Terrace, Chester Road West, Sunderland ... ... (S) Mar. 1898
Dunlop, William, c/o Messrs. Odero fu Aless°., Sestri-Ponente, Italy (E) Mar. 1888
Dyer, Charles M. B., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E SUR) Oct. 1892
Dykes, George, Lloyd's Register of Shipping, Steinhoeft 3, Hamburg ... ... (S) Jan. 1893
Dykes, James, 82, Park Road, Newcastle-upon-Tyne ... ... (E) May 1885
Dykes, John, Lloyd's Register of Shipping, Oriel Chambers, Liverpool ... ...(SUR) Oct. 1889

E.

Edminson, Frank A., Ormidale, Otterburn Villas, Newcastle-upon-Tyne ... ... (S) { Graduate, Nov. 1893 / Member, Nov. 1897
Edmiston, Jas. B., Ivy Cottage, Highfield Road, Walton, Liverpool (E) Nov. 1886
Edwards, Guy W., 89. Holly Avenue, Newcastle-upon-Tyne ... (E) Mar. 1897
Edwards, James Harry, Jun., High Docks, South Shields... ... (S) Mar. 1893
Eeles, Robert, Queen Street, Newcastle-upon-Tyne ... ... (E) April 1889
Egan, James, 72, Riviera House, Collingwood Road, West Hartlepool ... ... (E) Dec. 1893
Eidman, William, 1, Gay Street, Penarth ... ... (E) Nov. 1897
Elder, Edward, c/o Messrs. J. & G. Thomson, Clydebank, Glasgow ... ... (S) { Graduate, Nov. 1890 / Member, Oct. 1892
Elliott, William D., Hessle, Hull ... ... (E) Nov. 1894
Ellis, Robert Elwood, Messrs. Cumming & Ellis, Inverkeithing, Fife ... ... (S) Feb. 1891
English, Thos. (Lieut.-Col.), Hawley, near Dartford, Kent ... (E) Oct. 1890
Erdtman, Herman, c/o Mr. W. Lindberg's Varf, Stockholm, Sweden ... ... (E) Nov. 1893
Eshelby, William, 13, Brankingham Terrace, Norton Road, Stockton-on-Tees ... ... (E) Feb. 1888

ELECTED.

Evans, Charles H., c/o Messrs. The Vulcan Shipbuilding and Engineering Co., Stettin, Germany ... ... (E) Mar. 1891
Evans, Lewis, c/o Ralph Carr, Esq., Maritime Buildings, King Street, Newcastle-upon-Tyne ... ...(SUR) Dec. 1890
Evans, William, Superintendent Engineer, Rosedene, Whitchurch, Cardiff ... ... (E) Nov. 1889
Evans, William T., c/o Messrs. John Cory & Sons, Mount Stuart Square, Cardiff ... ... (E) Mar. 1896
Ewen, Alex., 22, Albany Terrace, Whitley, near Newcastle-upon-Tyne ... ... (E) { Graduate, Oct. 1891; Member, Jan. 1894 }

F.

Fairbairn, James, 54, Amberly Street, Sunderland... (E) { Graduate, May 1885; Member, April 1895 }
Farina, A. J., 63, Quayside, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Faruffini, Capt. M. C., c/o Connitato Pei Designa delle Navi Ministero dilla Marina, Rome, Italy ... ... (N A) Dec. 1888
Fenwick, James, B.Sc., C.E., 19, Bridge Street, Sydney, New South Wales ... ... (E) Oct. 1892
Ferrier, Robert M., B.Sc., Durham College of Science, Barras Bridge, Newcastle-upon-Tyne ... ... (E) Nov. 1892
Field, Arthur M. C., 110, Sandyford Road, Newcastle-upon-Tyne (E E) Jan. 1898
Finch, Herbert K., Colliery Agent, c/o Messrs. Blainscough Colliery Co., Coppull, near Chorley, Lancashire (E) { Graduate, Dec. 1888; Member, Nov. 1894 }
Findlay, John Taylor, 14, Nelson Street, Sunderland ... ...(SUR) Feb. 1890
Fish, Thomas Wilson, Lloyd's Register of Shipping, Calcutta, British India ... ...(SUR) May 1892
Fleming, Charles Edward, 71, Elswick Road, Newcastle-upon-Tyne (E) Nov. 1884
Fletcher, Robert, Walker Forge, Walker-on-Tyne ... ...(F M) Dec. 1886
Flohr, Justus, Director der Stettiner Maschinenbau-Actien-Gesellschaft "Vulcan," Kantstrasse 9, Stettin ... ... (E) Oct. 1886
Foley, Wm. C. le B., Box 537, Newport News, Virginia, U.S.A. ... ... (S) { Graduate, Nov. 1887; Member, Oct. 1892 }
Ford, David, c/o Messrs. J. Boyd & Co., Shanghai, China ... ... (E) May 1891
Ford, John McLaren, 70, Mount Pleasant, Barrow-in-Furness ... (S) Nov. 1896
Forster, Alfred Lindsay, 23, Noble Terrace, Gateshead (E) { Graduate, Nov. 1891; Member, Oct. 1895 }
Forster, William, c/o Messrs. Dixon, Robson, & Co., 2, Collingwood Street, Newcastle-upon-Tyne ... ... (E) Mar. 1890
Foster, Henry, c/o Messrs. Galloway & Co., Knott Mills Ironworks, Manchester ... ... (E) April 1885
Fothergill, J. R., Dock Office, West Hartlepool ... ... (C E) Mar. 1886
Fowell, Ridley, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ...(S & E SUR) Feb. 1893
Fownes, Henry, Tyne Forge, Ouseburn, Newcastle-upon-Tyne ... (F M) Nov. 1884
Fox, Samson, Messrs. The Leeds Forge Co., Leeds (*Life Member*) (E) Dec. 1887
Fox, William, 9, Winfield Terrace, Chester Road, Manchester ... (E) April 1895
Franki, J. P., c/o Messrs. Morts Dry Dock and Engineering Co., Sydney, N.S.W., Australia ... ... (E) Jan. 1886
Fraser, John Holt, 34, Balliol Road, Bootle, Liverpool (E) { Graduate, Oct. 1895; Member, Jan. 1898 }

ELECTED.

Fraser, Thomas S., 1, The Hollies, Armley, Leeds ... ... (E E) Jan. 1894
Furneaux, J. B., Victoria Engine Works, Gateshead-on-Tyne ... (E) Nov. 1885
Furse, Fred., Villa Schlaepfer, Capodimonte, Naples ... ... (S) April 1887

G.

Gad, Oscar, Deptford Shipyard, Deptford, Sunderland ... ... (S) Nov. 1893
Gaine, Roger L., 8, Humbledon View, Sunderland... (E) { Graduate, Dec. 1887; Member, Oct. 1894 }
Gannaway, H. G., 11, Kent Street, Jarrow-on-Tyne ... ... (S) Nov. 1884
Garelli, Fabio, *via* Settembre, Sestro Ponente, Italy ... ... (S) Oct. 1896
Garthwaite, John R., c/o Messrs. R. Ropner & Sons, Stockton-on-Tees (S) May 1889
Gayner, Robt. H., Jun., Beech Holm, Sunderland ... (E) { Graduate, Mar. 1886; Member, Oct. 1888 }
Gearing, Ernest George, Penshurst, Clarence Drive, Harrogate ... (E) Dec. 1892
Geddes, Christopher, 2A, Drury Lane, Water Street, Liverpool ... (E) Oct. 1888
Gibson, David, 18, Wadsworth Avenue, Cardiff ... ... (E) June 1896
Gibson, H., 162, Roker Avenue, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, J. Hamilton, c/o Messrs. Laird Bros., Birkenhead (E) { Graduate, April 1891; Member, Oct. 1894 }
Gibson, Thomas, 162, Roker Avenue, Sunderland ... (E) { Graduate, Nov. 1893; Member, Dec. 1897 }
Gibson, W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884
Golledge, William, Royal Agricultural Hall, Islington, London ... ... (E E) { Graduate, Nov. 1891; Member, Nov. 1896 }
Good, Farrant, c/o Messrs. Bute Dry Dock Co., Ltd., Roath Basin, Cardiff ... ... (E) Mar. 1896
Gordon, William James, c/o Messrs. Vickers, Sons & Co., Naval Construction Works, Barrow-in-Furness ... ... (E) Oct. 1887
Gordon, William Leslie, Invermark, Broughty Ferry, N.B. ... (E) April 1893
Graham, James Thos., 126, Westmorland Road, Newcastle-upon-Tyne ... ... (E) Nov. 1897
Graham, William, 8, Otto Terrace, Sunderland ... ... (S) Nov. 1884
Graham, William, West House, Tynemouth ... ... (S) Oct. 1891
Graham, William, 30, Hill Street, Jarrow-on-Tyne ... ... (S) April 1893
Graham, William, Primrose Villa, Kingsland Crescent, Barry Docks, South Wales ... ... (E) Nov. 1894
Gravell, John, Bureau Veritas Register of Shipping, 155, Fenchurch Street, London, E.C. ... ... (N A SUR) Nov. 1884
Gray, A., 17, Belgrave Terrace, Newcastle-upon-Tyne ... ... (E) Nov. 1888
Gray, George, 3, Cedars Crescent, Ryhope Road, Sunderland ... (E) Feb. 1888
Gray, Harry, Dominion House, 110, Fenchurch Street, London, E.C. ... ... (E) Dec. 1885
Gray, Sir William, Messrs. W. Gray & Co., West Hartlepool (S & E) Oct. 1888
Green, W. G., c/o Messrs. Chantiers Naval de Nicolaieff, a Bouffioulx, Hainaut, Belgium ... ... (E) Nov. 1884
Greenhow, John, 7, North View Terrace, Middlesbrough ... (S) Oct. 1894
Greig, David William, Messrs. Lymington Shipbuilding Co., Lymington, Hants. ... ... (E) Mar. 1891
Grey, Charles, 17, Lovaine Crescent, Newcastle-upon-Tyne ... (E) Feb. 1898
Griffith, Edwin, St. Alban's Place, Tynemouth ... ... (E) Nov. 1897

ELECTED.

Grimes, Thomas Benjamin, 39, Vespasian Avenue, South Shields... (E) Mar. 1890
Gross, Felix, 4, Collegiate Crescent, Sheffield ... ... (I & S M) Feb. 1893
Gulston, A., Clayton Park Lodge, Jesmond, Newcastle-upon-Tyne (E) Dec. 1888
Gunn, Sir John, Chairman, Messrs. Mount Stuart Dry Docks Co., Cardiff (*Life Member*) ... ... June 1896

H.

Hake, G. A., 29, Rothbury Terrace, Heaton, Newcastle-upon-Tyne (SUR) Oct. 1888
Hall, Edward, 68, Grange Road West, Jarrow-on-Tyne ... ... (S) Nov. 1885
Hall, J. Percy, Carville, Lawrie Park Road, Sydenham, London, S.E. (E) Oct. 1885
Hamilton, Robert C., The College, Durham... ... (E) { Graduate, Dec. 1892; Member, Oct. 1895 }
Hammar, Hugo G., Lindholmens, Verkstads Aktreholag, Göteberg, Sweden ... ... (S) Nov. 1890
Haramilshi, M., 13, Eversley Place, Heaton, Newcastle-upon-Tyne ... ... (N A) Nov. 1897
Harbottle, John, 63, Malvern Street, Newcastle-upon-Tyne ... (E) Oct. 1896
Harkness, Richard, Grange Road, West Hartlepool ... (S SUR) Nov. 1884
Harlow, F., 8, Benton Terrace, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Harman, Bruce, Messrs. The Linde British Refrigerating Co., 35, Queen Victoria Street, London, E.C. ... ... (E) Oct. 1886
Harper, J. H., 1, Beaumont Street, North Shields ... ... (E) Jan. 1885
Harris, Anthony, Clyde Yacht Club House, Hunter's Quay, Argyleshire... ... ... (E) Mar. 1892
Harrison, Alfred, Scotia Engine Works, Sunderland ... ... (E) Oct. 1889
Harrold, Alexander, 26, Park Road, Newcastle-upon-Tyne ... (E) Nov. 1884
Harrold, F., 140, Cardigan Terrace, Heaton, Newcastle-upon-Tyne (E) Nov. 1888
Harroway, George Mitchell, 8, Cambridge Terrace, Borough Road East, Middlesbrough ... ... (S) Jan. 1896
Hartley, W. A., c/o Messrs. Charles Cammell & Co., Sheffield ... (E) Jan. 1898
Harvey, John W. J., 1, Richmond Villa, Chertsey Road, Redland, Bristol ... ... (E) Feb. 1889
Hayashi, Kazuo, 7, Warrington Road, Newcastle-upon-Tyne ... (E) Jan. 1898
Head, Archibald P., 47, Victoria Street, London, S.W. (E) { Graduate, Nov. 1884; Member, Oct. 1887 }
Headlam, Robert, New Park Terrace, Hartburn Lane, Stockton-on-Tees ... ... (E) Nov. 1886
Heaviside, Arthur West, 7, Grafton Road, Whitley, near Newcastle-upon-Tyne ... ... (E E) Oct. 1896
Heck, John H., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (S SUR) Nov. 1885
Hemphill, Henry, 15, North View, Heaton, Newcastle-upon-Tyne (E) April 1897
Henderson, Alex., c/o Messrs. Empreza, Nacional, De. Nav. D'Vapor, Lisbon ... ... (E) April 1893
Henderson, A. M., 3, Greatham Terrace, West Hartlepool ... (E) Nov. 1890
Henderson, George, 54, Westmorland Road, Newcastle-upon-Tyne (E) Nov. 1884
Henderson, John, 1, Broadhurst Street, St. Michael's, Liverpool ... (N A) June 1896
Henry, William P., Cragside, St. Aidan's Road, South Shields ... (E) April 1897
Henshall, Samuel, 7, Lennox Street, Middlesbrough (S) { Graduate, May 1885; Member, Jan. 1894 }

ELECTED.

Hepburn, Alfred, Northumberland Forge, Wallsend-on-Tyne ... (F M) Dec. 1890
Hepple, William, Slipway, Wapping Street, South Shields... (E & S) Oct. 1885
Hepple, William Thos., Messrs. Hepple & Co., Engineers, Wapping Street, South Shields ... ... (E) Dec. 1893
Hesketh, Thomas, Bryn Tirion, Richmond Road, Cardiff ... ...(SUR) April 1896
Higgins, C. F., c/o Messrs. T. Richardson & Sons, Ltd., Hartlepool (E E) Feb. 1898
Hildrey, A. J., 11, Newcastle Road, Sunderland ... ... (S) Nov. 1884
Hill, Maxwell, 7, The Side, Newcastle-upon-Tyne ... ...(N A) Nov. 1884
Hindson, William Forster, 19, Ravensworth Terrace, Gateshead-on-Tyne ... ... (E) { Graduate, Nov. 1891; Member, Nov. 1892
Hirst, Richard, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ... (E SUR) Nov. 1885
Hodge, Rowland F. W., c/o Messrs. The Northumberland Shipbuilding Co., Limited, Northumberland Shipyard, Howdon-on-Tyne ... ... (S) Dec. 1890
Hodgson, Rich., Bowness, Gordon Street, Workington ... ... (S) Dec. 1896
Hogg, Archibald, Netherleigh, Beach Avenue, Whitley, Northumberland ... ... (S) Jan. 1897
Hogg, James, 8, Lovaine Terrace, North Shields ... ... (B F) Nov. 1889
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Holgate, Charles H., School Close Works, Leeds ... ... (E) Feb. 1895
Hollis, Henry William, Whitworth House, Spennymoor ... ... (I M) Oct. 1891
Holmes, John H., Portland Road, Newcastle-upon-Tyne ... ... (E E) Jan. 1888
Homji, A. C. N., c/o Messrs. Lakhmidas Khimji S. & W. Co., Limited, Fergusson Road, Bombay, India ... ... (E) Nov. 1884
Hooper, Ernest, 24, Whitehall Terrace, Hylton Road, Sunderland (E) Nov. 1885
Houston, John, 32, Randolph Street, Sunderland ... ... (E) Nov. 1894
Hovgland, Even, Lloyd's Surveyor, Bergen, Norway ... ... (E) Dec. 1896
Hughes, Thos. Charles, 3, Summerhill Street, Newcastle-upon-Tyne ... ... (E) { Graduate, Nov. 1893; Member, Nov. 1897
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
Hunter, J. W., 10, Princess Road, Stockton Road, Sunderland ... (E) May 1885
Hunter, Summers, c/o Messrs. N.E. Marine Engineering Co., Northumberland Engine Works, Wallsend-on-Tyne ... ... (E) Nov. 1885
Hutchinson, C. W., 6, Park Parade, Westmorland Road, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Hutchinson, Wesley, B.A., 6, Park Parade, Westmorland Road, Newcastle-upon-Tyne ... ... (E) Oct. 1891
Hutchison, J., Board of Trade Offices, Middlesbrough ... ...(SUR) Dec. 1891
Hutchison, Thomas Allan ... ... (S) Nov. 1891

I.

Inglis, John, c/o Messrs. Hawthorn & Co., Leith ... ... (S) April 1887
Inglis, John, Pointhouse Shipyard, Partick, Glasgow ... (E & S) Oct. 1886
Inman, Douglas S., Fairholm, Heaton, Newcastle-upon-Tyne ... (E) Oct. 1892
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884
Ives, Bernard, c/o Messrs. The Northumberland Shipbuilding Co., Northumberland Shipyard, Howdon-on-Tyne ... ... (S) Feb. 1898

ELECTED.

J.

Jack, Charles Kellie, 35, Cranbourne Terrace, Stockton-on-Tees... (S) Nov. 1897
Jack, William C., c/o Messrs. The Hong Kong & Whampoa Dock Co., Limited, Hong Kong, China ... ... (E) Nov. 1894
Jackson, Albert S., 3, Mount Stuart Square, Cardiff ... ... (E) Mar. 1896
Jackson, William S., Messrs. Gourlay Bros. & Co., Camperdown Shipyard, Dundee... ... ... (S) April 1891
James, M. C., 6, Park Terrace, Gateshead-on-Tyne ... ... (S) Nov. 1884
Jennings, Frederick, 13, Eversley Place, Heaton, Newcastle-upon-Tyne ... ... (E) Feb. 1898
Jewitt, Charles Wm., West Park View, Stanhope Road, South Shields ... ... (E & S) Nov. 1897
Jobling, J. C., Blackwall Ironworks, Isle of Dogs, London, E. ... (E) Nov. 1884
Jobling, W. J., 1, Akenside Hill, Newcastle-upon-Tyne ... (E & S O) Nov. 1884
Jobson, H. G., Exchange Buildings, West Hartlepool ... ...(SUR) June 1896
Jobson, Robert, Jun., Clifton Avenue, West Hartlepool ... ... (S) Feb. 1898
Johnson, Alexander, 9, Cheltenham Terrace, Heaton, Newcastle-upon-Tyne ... ... (E) Feb. 1893
Johnson, Johan, 7, Vestra Hamngaten, Gothenburg, Sweden ... (S) May 1885
Johnson, T. Allan, Dry Docks, Passage West, Cork ... ... (S) Nov. 1884
Johnstone, William, Lloyd's Register of Shipping, Barrow-in-Furness ... ...(SUR) Nov. 1884
Joicey, Jacob G., Forth Banks West Factory. Newcastle-upon-Tyne (E) Jan. 1889
Jones, Charles, 10, Glynrhondda Street, Cardiff ... ... (E) Mar. 1896
Jones, George, c/o Messrs. W. Gray & Co., West Hartlepool ... (S) Oct. 1888
Jones, Morlais G., 6, Delahay Street, Westminster, London, S.W. (E) Nov. 1887

K.

Kaneda, Wasaburo, c/o Messrs. J. & G. Thompson, Clydebank, Glasgow ... ... (SUR) Nov. 1897
Keene, H. R., Lloyd's Register of Shipping, Ouest Quai, 28, Katendyk, Antwerp ... ... (E) { Graduate, May 1885; Member, April 1887
Kendall, Stonard O., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ...(SUR) Mar. 1891
Kerfoot, James, 45, Rue de Grand Chila, Zurenberg, Antwerp ... (E) Oct. 1892
King, John, 16, Lefroy Street, Newcastle-upon-Tyne (S) { Graduate, Dec. 1890; Member, Oct. 1892
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885
Kitching, J. F., Clifton Avenue, West Hartlepool ... ... (E) Nov. 1890

L.

Lace, Basil T., 10, Heaton Grove, Heaton, Newcastle-upon-Tyne ... ... (E) { Graduate, Nov. 1895; Member, Nov. 1897
Laing, Andrew, c/o Messrs. Wallsend Slipway and Engineering Co., Wallsend-on-Tyne ... ... (E) Oct. 1892
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 1884
Laing, Hugh, Deptford Shipyard, Sunderland ... ... (N A) April 1897
Laing, John, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E) Nov. 1884

ELECTED.

Landreth, Cowen, 34, Simonside Terrace, Newcastle-upon-Tyne ... (E) Mar. 1896
Lang, William Veysey, Messrs. Allsop & Co., Shipbuilders and Engineers, Preston, Lancashire... ... ... (E) Nov. 1897
Larkin, James, Tyne View, East Jarrow-on-Tyne ... ... (E) Nov. 1884
Lewins, Frank, Rosehill, Willington Quay-on-Tyne ... ... (E) Dec. 1895
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne ... ... (E) Nov. 1884
Liddell, J., c/o Messrs. Denny & Co.. Engine Works, Dumbarton (E) Nov. 1884
Lie, Gotfred, Det Bergenske Dampskibsselskab, Bergen ... ... (E) Jan. 1895
Lindfors, Hugo, Surveyor to Lloyd's Register of Shipping, 16, Alexandersgatan, Helsingfors, Finland ... ... (SUR) May 1889
Lineham, Wilfrid J., Jesmond, Leyland Road, Lee, London, S.E. (E) Oct. 1890
Linsley, Frederick, 5, Wentworth Terrace, South Shields... ... (E) Jan. 1896
Littleboy, Chas. Wm., The Woodlands, Saltburn-by-the-Sea ... (S) Oct. 1887
Littledale, John W. E., 74, Warrington Road, Newcastle-upon-Tyne (E) May 1896
Livingston, Thos. L., Dunedin House, Jarrow-on-Tyne ... ... (S) Nov. 1884
Lohmeyer, H., 53, Crown Street, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Long, A. E., 124, Albert Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Lowdon, David, Messrs. The Barry Graving Dock and Engineering Co., Limited, Barry Dock, near Cardiff ... ... (E) May 1894
Lowdon, John, Messrs. The Barry Graving Dock and Engineering Co., Limited, Barry Dock, near Cardiff ... ... (E) Dec. 1891

M.

MacColl, Hector, Bloomfield, Belfast ... ... (E) Dec. 1890
MacColl, Hugo, Wreath Quay Engineering Works, Sunderland ... (E) Nov. 1896
Maccoy, John, 55, Larkspur Terrace, Newcastle-upon-Tyne ... (E) Feb. 1886
Macdonald, Charles, 4, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ...(SUR) Feb. 1898
MacDonald, David R., c/o Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd., Walker Shipyard, Newcastle-upon-Tyne (S) Nov. 1891
Mace, W., 253, Albert Road, Jarrow-on-Tyne ... ... (E) Jan. 1886
MacGregor, John, 2, Michaelston Villas, Barrow-in-Furness ... (E) Mar. 1888
MacHaffie, John, 635, Terrace Place, Schenectady, New York, U.S.A. (E) Dec. 1885
Mackay, William, 8, Camperdown Cottages, Whiteinch, near Glasgow ... ... (S) Mar. 1892
Mail, M., Jun., 8, Ashbrook Terrace, Sunderland ... ... (E) Nov. 1897
Mair, James, Wh. Sc., 24, Dockwray Square, North Shields ... (E) Oct. 1894
Malin, Reginald P. H., 183, Hugh Gardens, New Benwell, Newcastle-upon-Tyne ... ... (E) Jan. 1898
Manaira, Guiseppe, 4, Salita S Gerslamo, Genoa, Italy ... (E & N A) Nov. 1893
Marr, James, c/o Messrs. J. L. Thompson & Sons, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Marshall, F. C., 38, Percy Gardens, Tynemouth ... ... (E) Nov. 1884
Marshall, Frank T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E) { Graduate, Jan. 1885 / Member, Oct. 1888
Marshall, R. J., 51, Larkspur Terrace, Jesmond, Newcastle-upon-Tyne... ... ... (E) Mar. 1887
Maslen, Frank E., 14, Belsize Park Gardens, Hampstead, London, N.W. ... ... (E) { Graduate, Nov. 1891 / Member, May 1898
Mason, George F., Lloyds' Bank Buildings, Mount Stuart Square, Cardiff ... ... (E) Oct. 1895

ELECTED.

Mastaglio, W. D., 65, Warrington Road, Newcastle-upon-Tyne ... (E) Nov. 1885
Mather, Charles, 44, Warrington Road, Newcastle-upon-Tyne ...(SUR) Oct. 1888
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne... ... ... (S) Dec. 1889
Matsuda, Mantaro, 7, Warrington Road, Newcastle-upon-Tyne ... (E) Jan. 1898
Matthews, A., c/o Messrs. Blyth Shipbuilding Co., Blyth... ... (S) Nov. 1884
Matthews, Jas., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-upon-Tyne ... ... (E) Oct. 1886
Maxwell, William Ward, Messrs. H. Charlton & Co., Engineers, Gateshead-on-Tyne ... ... (E) Dec 1896
McBride, William, Beaconsfield Square, Hartlepool ... ... (E) Dec. 1894
McGlashan, Arch., Beechcroft, Clifton Avenue, West Hartlepool (S) Nov. 1885
McIlvenna, J. G., c/o Messrs. The Tyne Pontoons and Dry Docks Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
McKechnie, James, Messrs. Vickers, Sons, & Co., Naval Construction Works, Barrow-in-Furness ... ... (E) April 1896
McKenna, Francis, c/o Messrs. E. F. Wailes & Co., 4, St. Nicholas' Buildings, Newcastle-upon-Tyne ... (E) { Graduate, Dec. 1890; Member, Dec. 1896 }
McLaren, Robert M., Flinton Hill, Sunderland ... ... (S) Nov. 1893
McLaren, William, 16, Rock Park, Rock Ferry, Cheshire ... ... (E) Oct. 1894
McLean, John H. K., Abey House, Plotina Terrace, South Shields (S) Mar. 1897
McNeil, Thomas Young, Ship Drawing Office, Messrs. The Clydebank Engineering and Shipbuilding Co., Glasgow ... ... (S) Oct. 1895
Meagher, H. L., Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd., Elswick Ordnance Works, Newcastle-upon-Tyne ... (E) Dec. 1896
Mechan, Henry, c/o Messrs. Mechan & Sons, Cranstonhill, Glasgow (E) May 1898
Meldrum, Michael, Humbledon View, Sunderland ... ... (E) Dec. 1893
Mellanby, Alex. Lawson, B.Sc., Fernleigh, Grange Road, West Hartlepool ... ... (E) { Graduate, Dec. 1894; Member, Oct. 1896 }
Menzies, Wm., The Side, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Messenger, Thomas, Paris House, Snargate Street, Dover, Kent ... (E) Mar. 1887
Metcalf, Thos., 18, John Street, Sunderland... ... (S) { Graduate, May 1885; Member, Nov. 1893 }
Metcalfe, C. S., 24, Croft Avenue, Sunderland ... ... (E) Nov. 1884
Micheli, Pietro, Jun., Via Sottoripu, No. 1, piano nobile, Genoa, Italy ... ... (E & N A) Oct. 1888
Middlemass, Thomas, 3, Albert Place, Norton Road, Stockton-on-Tees... ... ... (S) Oct. 1889
Middleton, H., 20, Lynnwood Avenue, Newcastle-upon-Tyne (I & S M) Jan. 1893
Middleton, Robert Alexander, 4, Ashville, Skeigoneil Avenue, Belfast, Ireland ... ... (N A) Oct. 1892
Millar, Thos., c/o Messrs. Sir W. G. Armstrong, Whitworth, & Co., Ltd., Walker Shipyard, Walker-on-Tyne ... ... (S) Nov. 1884
Mills, John, 7, Ledard Street, Langside, Glasgow ... ... (E) Feb. 1888
Mills, William, Atlas Works, Bonners Field, Sunderland ... ... (E) Feb. 1890
Milton, J. T., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Nov. 1886
Moffatt, James, 7, Murray's Terrace, Belfast, Ireland (E) { Graduate, Dec. 1889; Member, Oct. 1892 }
Moffitt, George, c/o Messrs. The Blyth Shipbuilding Co., Blyth ... (S) Oct. 1888
Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885

ELECTED.

Moffoot, Alexander, 43, Bedford Street, North Shields ... ... (S) Mar. 1898
Montgomerie, Hugh, 38, King John Terrace, Heaton, Newcastle-upon-Tyne ... ... (S) Nov. 1897
Moody, Thomas V., 7, The Grove, Gosforth, Newcastle-upon-Tyne (E) Dec. 1887
Moore, Frederick, c/o Messrs. Wilson, Sons, & Co., Ltd., Bahia ... (E) Oct. 1890
Moore, Wm. Henry, 18, George Road, Wallsend-on-Tyne ... ... (E) Nov. 1897
Moorsom, Frederick, Victoria Road, West Hartlepool ... ... (S) Feb. 1898
Morgan, W. H., 22, Rochdale Street, Wallsend-on-Tyne ... ... (E) Nov. 1884
Morison, D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885
Mörk, Peter, 31, Holsteinsgude, Copenhagen ... ... (E) Nov. 1884
Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886
Morrison, William, Lloyd's Register of Shipping, Maritime Buildings, Dundee ... ... (E SUR) Oct. 1890
Morton, David, 126, Aurelian Terrace, South Shields ... ... (S) Feb. 1898
Morton, Richard Fraser, Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E SUR) Oct. 1890
Mould, Francis H., 36, Salter's Road, Gosforth, Newcastle-upon-Tyne ... ... (E) { Graduate, Feb. 1892; Member, Jan. 1897 }
Mountain, William Chas., Messrs. Ernest Scott, Mountain, & Co., Close, Newcastle-upon-Tyne ... ... (E E) Feb. 1889
Muir, Alfred Edward, 13, Joannah Street, Sunderland ... ... (S) Mar. 1893
Muir, Robert, 11, Clarence Crescent, Whitley, near Newcastle-upon-Tyne ... ...(SUR) Oct. 1886
Muir, Robert Home, 1, Lovaine Crescent, Newcastle-upon-Tyne ... (S) Oct. 1892
Musgrave, Evers, 147, St. Owen Street, Hereford ... (E) { Graduate, Nov. 1891; Member, Oct. 1895 }
Myles, David, Northumberland Engine Works, Wallsend-on-Tyne (E) Nov. 1884

N.

Nastoupil, John, Chief Engineer, Austro-Hungarian Navy, Marine Casino, Pola, Austria ... ... (E) Nov. 1890
Neill, William Reid, 15, Salem Hill South, Sunderland ... ... (E) Dec. 1897
Nevins, William, 28, Brookbank Road, Lewisham, London, S.E.... (E) Mar. 1894
Newton, Richard, Park Square, West Hartlepool ... ... (E) April 1889
Nichol, Bryce G., 84, Third Avenue, Heaton, Newcastle-upon-Tyne ... ... (E) { Graduate, Oct. 1891; Member, May 1898 }
Nicholls, H. E., 25, Churchill Street, Sunderland ... ... (E) Nov. 1893
Nichols, Walter W., 30, Denmark Street, Gateshead-on-Tyne ... (E) May 1895
Nicholson, John S., North View, Mowbray Road, Westoe, South Shields ... ... (E) Nov. 1893
Nicholson, Joseph Cook, Collingwood Street, Newcastle-upon-Tyne (E) Feb. 1897
Nicholson, Thos. Head, 90, Rye Hill, Newcastle-upon-Tyne ... (E) Nov. 1897
Nicholson, Walter E., Hebburn Boiler Works, Hebburn-on-Tyne (B B) April 1896
Nicol, John M., 15, Linskill Terrace, North Shields ... ... (E) Nov. 1884
Nicolson, G. C., H.M.S. "Rambler," Surveying Service (E) { Graduate, Oct. 1885; Member, Oct. 1888 }
Noble, George, 7, Dean Street, Newcastle-upon-Tyne ... ... (E) May 1893
Noble, Harry, Northern Machine Tool Works, Brewery Lane, Felling-on-Tyne ... ... (E) Nov. 1888
Nodder, Joseph, Ash Lea, Crabtree, Sheffield ... ... (F M) May 1893

ELECTED.

Norman, W. S., Orchard House, Whitby, near Chester ... ... (E) Nov. 1884
Norton, Harold P., Engineer Corps U.S. Navy, Washington, U.S.A. ... ... (E) Oct. 1890
Noton, F. R., Lloyd's Register of Shipping, Bute Docks, Cardiff (S) Nov. 1884
Nunes, Enrique E., Engineer, Argentine Navy, 433, Calle Ayacucho, Buenos Ayres ... ... (E) April 1891

O.

O'Halloran, Timothy, 205, Avenue du Commerce, Antwerp, Belgium ... ... (E) Jan. 1895
O'Neil, J. J., 2, Erith Terrace, Sunderland ... ... (E) Nov. 1884
Ord, Godfrey C., The Esplanade, Sunderland ... ... (E E) Jan. 1897
Orde, E. L., c/o Messrs. Sir W. G. Armstrong, Whitworth, & Co., Ltd., Walker Shipyard, Newcastle-upon-Tyne ... ... (E) Oct. 1887
Orlando, Chev. Giuseppe, Cantiere Navale, Fratelli Orlando, Leghorn ... ... (N A) Jan. 1893
Ormonde, John Grey, 35, Percy Gardens, Tynemouth ... ... (E) Nov. 1897
Orr, John, B.Sc. ... ... (E) Mar. 1897
Orr, Reginald, Kent Villa, Roxborough Park, Harrow-on-the-Hill, Middlesex ... ... (E) { Graduate, Mar. 1890; Member, Oct. 1892 }
Oxley, G., 39, Norman Terrace, Howdon-on-Tyne ... ... (S) Nov. 1884
Oxton, Walter, 96, Blackpool Street, Burton-on-Trent (E) { Graduate, Dec. 1890; Member, May 1894 }

P.

Pacey, John W., 3, Main Street, Stapenhill, Burton-on-Trent ... (E) Feb. 1888
Parsons, Hon. Charles A., Holeyn Hall, Wylam-on-Tyne ... ... (E E) Dec. 1887
Parsons, Harry F., c/o P. Brotherhood, Esq., Belvedere Road, Westminster Bridge, London, S.E. ... ... (E) Dec. 1890
Pascoe, J. R., Tyrmont, Woodford Green, Essex (*Life Member*) ... (S) Dec. 1889
Patterson, Jas., Hawthornden, Knock, Belfast, Ireland ... ... (E) Nov. 1884
Pattison, Jos., 123, Bute Road, Cardiff ... ... (E) Nov. 1884
Paulin, William J., 47, Clarence Crescent, Shieldfield, Newcastle-upon-Tyne ... ... (E) April 1897
Paulson, John ... ... (S) Feb. 1886
Payne, Henry Fernie, 15, Willowbank Road, Devonshire Park, Birkenhead ... ... (E) Dec. 1895
Pearson, James T., 11, Beech Grove Road, Newcastle-upon-Tyne .. .. (S) { Graduate, Nov. 1893; Member, Dec. 1897 }
Penney, R. H., Board of Trade Offices, 79, Mark Lane, London, E.C. ... ... (S SUR) Nov. 1884
Pepper, W., 9, West Villas, Oxbridge Lane, Stockton-on-Tees ... (E) Nov. 1888
Perrett, Jos. Richard, Victoria Villa, Low Fell, Gateshead-on-Tyne ... ... (N A) Nov. 1897
Petersen, John L., Havelock House, Victoria Road, West Hartlepool (SUR) Oct. 1888
Petree, James, Lloyd's Register of Shipping, Oriel Chambers, Water Street, Liverpool ... ... (N A SUR) Oct. 1885
Petrini, Giacomo Luigi, C.E., c/o Messrs. Gio Ansaldo & Co., Sestri-Ponente, Italy ... ... (N A) Nov. 1892
Petterson, Carl Edwin, 7, Vestra Hamngaten, Gothenburg, Sweden (E) Oct. 1891

ELECTED.

Philipson, Roland, Tynemouth... ... ... (E) Dec. 1884
Phorson, P., Glen Lea, Roker, Sunderland ... ... (S) Nov. 1884
Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris ... ... (N A) Nov. 1888
Piercy, Frank, 1, Bolton Terrace, Newcastle-upon-Tyne ... ... (E) Dec. 1896
Pirrie, Norman, Brook House, 10, Wallbrook, London, E.C. ... (E) Nov. 1897
Pitt, Frederick William, 550, Chester Road, Old Trafford, Manchester ... ... (E SUR) Oct. 1890
Poli, Rodolfo, Chioggia, Italy ... ... (N A) Jan. 1890
Pollard, T., 43, Second Avenue, Heaton, Newcastle-upon-Tyne ... (E) Dec. 1896
Potts, Cuthbert Ivan, 6, Rodsley Avenue, Gateshead-on-Tyne ... (E) Oct. 1895
Potts, Robert L., 11, Mount Pleasant, Deptford, Sunderland ... (S) Oct. 1888
Powell, James Richard, 89, Exchange, Mount Stuart Square, Cardiff ... ... (C E) May 1894
Price, F. D., 6, Osborne Villas, Jesmond, Newcastle-upon-Tyne (E & S) Oct. 1888
Price, John, 6, Osborne Villas, Jesmond, Newcastle-upon-Tyne ... (S) Nov. 1884
Pringle, Alfred, 10, Somerset Terrace, Walker-on-Tyne (S) { Graduate, Dec. 1891 / Member, Jan. 1894
Pringle, James G., 10, Somerset Terrace, Walker-on-Tyne... ... (S) Oct. 1892
Prosser, James, 9, Suffolk Street, Jarrow-on-Tyne ... ... (E) Nov. 1893
Purdon, Andrew S., Messrs. Irvine's Shipbuilding and Dry Docks Co., Limited, West Hartlepool ... ... (S) Oct. 1892
Purdy, A. J., Shipyard Drawing Office, Newport News, Virginia, U.S.A. ... ... (E) Nov. 1884
Purvis, Fred. W., 5, Greatham Terrace, West Hartlepool ... ... (S) April 1893
Putnam, T., Darlington Forge, Darlington ... ... (F M) Nov. 1884

Q.

Quicke, Herbert John, c/o Messrs. Harfield & Co., Blaydon Ironworks, Blaydon-on-Tyne ... ... (E) Feb. 1891

R.

Ramage, J. T., St. Aubyn's, Bonnington, Edinburgh ... ... (E) April 1887
Ramage, John Anderson, 74, Glen Terrace, Hebburn-on-Tyne ... (S) Oct. 1892
Readhead, Jas., Westoe Hall, South Shields ... ... (S) Nov. 1884
Readhead, John, 4, Salisbury Place, South Shields.. ... ... (E) Mar. 1886
Readhead, R., 28, Sea View Terrace, South Shields ... ... (E) Nov. 1884
Readhead, W. B., Beach View, South Shields .. .. (S) Nov. 1886
Reavell, W. ... ... (E) { Graduate, April 1885 / Member, Oct. 1887
Reed, James, Messrs. Palmer's Shipbuilding and Iron Co., Ltd., Jarrow-on-Tyne ... ... (S) Dec. 1897
Reed, Joseph, Angerton House, North Shields ... ... (E) Oct. 1889
Reed, J. W., c/o Messrs. Palmer's Shipbuilding and Iron Co., Limited, Engine Works Department, Jarrow-on-Tyne ... (E) Nov. 1884
Reed, Richard, 56, George Road, Wallsend-on-Tyne ... ... (S) Oct. 1894
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886
Renton, John, 1, Akenside Hill, Newcastle-upon-Tyne ... (M SUR) April 1895
Reynolds, Charles H., c/o Messrs. Sir W. G. Armstrong, Whitworth, & Co., Ltd., Walker-on-Tyne ... ... (S) Mar. 1889
Reynolds, W. G., 4, Ulfra Terrace, South Shields ... ... (E) Oct. 1886

ELECTED.

Richardson, Sir Thomas, B.A., M.P., Hartlepool Engine Works, Hartlepool ... ... (E) April 1888
Richardson, Wigham, Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Rickaby, A. A Bloomfield Engine Works, Sunderland ... ... (E) Mar. 1888
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Riley, J. H., Messrs. Riley Bros., Stockton-on-Tees ... ... (B B) May 1893
Ritson, M., Lloyd's Register of Shipping, 29, Regent Quay, Aberdeen ... ... (E SUR) Nov. 1884
Ritson, S. M., c/o J. H. Hallett, Esq., 123, Bute Docks, Cardiff ... ... (E) { Graduate, Nov. 1887; Member, Nov. 1893
Robinson, William, 20, Croft Avenue, Sunderland ... (E) { Graduate, May 1885; Member, April 1888
Robson, George, 9, Wellington Terrace, South Shields ... ... (E) Oct. 1889
Robson, George, 140, Aurelian Terrace, South Shields ... ... (E) Feb. 1896
Robson, John H., 16, Sunbury Avenue, Newcastle-upon-Tyne ... (E) Nov. 1885
Robson, J. M., 4, Abbey Terrace, Gateshead-on-Tyne ... ... (E) Nov. 1884
Robson, M., 20, Tavistock Place, Sunderland ... ... (S) Nov. 1884
Robson, Nathaniel E., 11, Point Pleasant Terrace, Wallsend-on-Tyne ... ... (E) { Graduate, Dec. 1894; Member, Nov. 1897
Roger, Robert, Stockton Iron Foundry, West Row, Stockton-on-Tees (E) Nov. 1888
Rogers, Herbert M., Redcliffe, Durham Avenue, Bromley, Kent (SUR) April 1889
Rolf, George, 9, Bentinck Terrace, Newcastle-upon-Tyne .. ... (E E) May 1892
Rolland, Alexander, Villa Ruzic Susak Fiume, Hungary... ... (E) Mar. 1892
Roper Leopold, Palace Chambers, Westminster, London, S.W. ... (N A) Dec. 1896
Ropner Robert, Jun Stockton-on-Tees ... ... (S) Feb. 1886
Rosen, Jacob, c/o Messrs. Craig & Taylor, Thornaby Shipyard, Stockton-on-Tees ... ... (S) Nov. 1897
Rosenthal, James H., Woodville, 97, Eltham Road, Lee, Kent ... (E) Dec. 1896
Rossetti, S., 90, Paradise Street, Liverpool ... ... (N A) June 1896
Ross, Charles, c/o Messrs. Smith's Dock Co., Ltd., North Shields... (E) Jan. 1898
Ross, William, 20, Meadow Side, Dundee ... ... (E) May 1893
Rosser, W. D., Messrs. The Cardiff Pontoon Company, Mount Stuart Square, Cardiff ... ... (S) Nov. 1893
Rowan, Jas., 231, Elliott Street, Glasgow ... ... (E) Nov. 1886
Rowell, G. W., 6, Armstrong Road, New Benwell, Newcastle-upon-Tyne ... ... (E) Feb. 1885
Rowell, H. B., Cleugh Brae, Jesmond East Park, Newcastle-upon-Tyne (*Life Member*) ... ... (S) Nov. 1884
Rusden, L., 4, Sanderson Road, Jesmond, Newcastle-upon-Tyne (E) Nov. 1884
Russell, F. Herbert, Scotia Engine Works, Sunderland ... ... (E) Oct. 1891
Rutherford, G., Messrs. Mercantile Pontoon Co., Roath Dock, Cardiff (S) Oct. 1886
Rutherford, J. T., 2, Umfraville Road, Harringay, London (E) { Graduate, Jan. 1886; Member, Nov. 1893
Ryder, C. L., c/o Messrs. The Universal Weldless Steel Tube Co., Chesterfield ... ... (E) Oct. 1886
Ryder, William J. H., Hartford Bridge House, Cramlington, R.S.O. (E) Oct. 1891

S.

Salmon, P., 5, The Oaks West, Sunderland ... ... (E SUR) Nov. 1884
Sambidge, James, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-upon-Tyne ... ... (E E) Nov. 1891

ELECTED.

Sandeman, John Watt, 2, St. Nicholas' Buildings, Newcastle-upon-Tyne... ... ... (E) Oct. 1891
Sanderson, Henry Thomas Barron, Messrs. Sanderson & Co., High Quay, Blyth ... ... (E) Oct. 1891
Sanderson, J., 31, Park Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Sandison, M., 12, Beech Grove Road, Newcastle-upon-Tyne ... (E) Dec. 1884
Sawyers, John, c/o Messrs. Thos. Wilson, Sons, & Co., Hull ... (E) Oct. 1886
Schaeffer, A. G., 32, Side, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Scotson, Wm., Fair View, Wood Green Road, Wednesbury ... (E) Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-upon-Tyne ... (E E) Nov. 1884
Scott, James, c/o Messrs. Consett Iron Co., Blackhill, Co. Durham (E) Oct. 1892
Scott, Joseph R., 9, Queen Street, Newcastle-upon-Tyne ... ... (E) Oct. 1887
Scott, Walter, 13, Charlotte Street, Ayr ... ... (N A) Mar. 1897
Scott, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Scott, William, 134, King's Road, Cardiff ... ... (E) June 1896
Scurfield, George G., 2, Percy Terrace, Sunderland ... ... (E) Mar. 1897
Seabury, Edward, Burnt Mill House, Harlow, Essex ... ... (E) Mar. 1886
Seaman, C. J., 134, High Street, North Stockton-on-Tees ... ... (E) Jan. 1889
Seaton, Albert Edward, Messrs. Earle's Shipbuilding Co., Hull ... (E) Jan. 1891
See, Horace, 1, Broadway, New York City, U.S.A. ... ... (E) May 1896
Shahd, H., 39, Holly Avenue, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Sharp, A. E., c/o Messrs. The Peninsular and Oriental Steam Navigation Co., 122, Leadenhall Street, London ... ... (E) Nov. 1884
Sharp, Mark, 144, Albert Road, Jarrow-on-Tyne ... ... (E) Dec. 1889
Shaw, Jas., 26, Sandhill, Newcastle-upon-Tyne ... ... (M SUR) Jan. 1885
Sheriff, Thomas, c/o Messrs. Robert Mackill & Co., 29, Waterloo Street, Glasgow ... ... (E) April 1890
Short, J. Y., 49, West Sunniside, Sunderland ... ... (S) Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland... ... ... (S) Nov. 1884
Shotton, John W., 32, Mount Stuart Square, Cardiff ... ... (SUR) Nov. 1886
Shute, A. E., 12, Clyde View, Partick, Glasgow ... ... (E) Dec. 1892
Sibun, William, Lloyd's Register of Shipping, Bute Docks, Cardiff (SUR) Mar. 1896
Sim, John Archibald, 1, South Cliffe, Roker, Sunderland ... ... (S) Jan. 1896
Simpson, Kenneth, c/o Messrs. R. and W. Hawthorn, Leslie, & Co., Shipyard, Hebburn-on-Tyne ... ... (S) { Graduate, Dec. 1893; Member, Oct. 1895 }
Sinclair, R., c/o Messrs. J. Wildridge & Sinclair, Consulting Engineers, 97, Pitt Street, Sydney, N.S.W., Australia ... (C E) Nov. 1884
Sinton, John K., 26, Sandhill, Newcastle-upon-Tyne ... ... (E) Nov. 1885
Sisson, Wm., Gloucester ... ... (E & N A) Oct. 1888
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool ... ... (S) Nov. 1886
Skinner, Leslie, Ravensbourne Terrace, South Shields (S) { Graduate, Dec. 1886; Member, Oct. 1891 }
Smith, C. E., Cowesby, Clifton Avenue, West Hartlepool ... (E) Nov. 1888
Smith, Eustace, 5, Queen Street, Newcastle-upon-Tyne ... ... (S) Nov. 1884
Smith, L. Eustace, 22, St. Mary's Place, Newcastle-upon-Tyne... ... ... (E) { Graduate, Oct. 1889; Member, Oct. 1892 }
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds (E) Oct. 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-upon-Tyne ... ... (E) April 1885
Smith, Wm., 152, Roker Avenue, Sunderland, M. ... ... (E) Nov. 1884

		ELECTED.
Smith, Wm. Stawart, West Villa, The Green, Wallsend-on-Tyne ... ... (S)	Graduate,	Nov. 1893
	Member,	Dec. 1897
Snook, Francis W. G., 83, Park Road, Newcastle-upon-Tyne ...	(E)	Dec. 1896
Soliani, Nabor, Col., Direttore del Cantiere Ansaldo, Sestri-Ponente, Italy	(S)	Jan. 1885
Sowter, Isaac G., c/o Messrs. Samuel F. Hodge & Co., 308, Atwater Street, Detroit, Michigan, U.S. America	(E)	Jan. 1889
Spark, H. King, Messrs. The Anti-Attrition Metal Co., Ltd., Emerson Street, Southwark, London, S.E.	(E)	May 1898
Spear, John, c/o Messrs. T. Wilson & Sons, Hull	(E)	Oct. 1887
Spearman, Richard, Eachwick House, Dalton, Newcastle-upon-Tyne	(E)	Feb. 1889
Spence, W. G., c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne (*Life Member*)	(E)	Nov. 1884
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne ...	(E)	Feb. 1885
Stafford, William, 233, Coatsworth Road, Gateshead-on-Tyne ...	(E)	Nov. 1885
Staig, William Andrew, Station Road, Wallsend-on-Tyne ...	(E)	Feb. 1897
Stansfield, George R., The Grove, Westoe, South Shields	(E)	Mar. 1891
Stephen, A. E., Linthouse, Govan, Glasgow	(E & S)	June 1896
Stephen, John Murray, Linthouse Engine Works, Govan, Glasgow	(E)	Oct. 1895
Stephens, H. C. J., 94, Fortess Road, Kentish Town, London, N.W. ... ... (E)	Graduate,	Oct. 1890
	Member,	Nov. 1897
Stephenson, Bernard, 12, Crown Terrace, Anlaby Road, Hull ...	(E)	Dec. 1896
Stephenson, C., 2, Elm Terrace, The Green, Wallsend-on-Tyne ...	(S)	Nov. 1884
Stevenson, Wm., Bank Chambers, Sandhill, Newcastle-upon-Tyne	(E)	Nov. 1884
Stewart, James, 31, Lily Avenue, Jesmond, Newcastle-upon-Tyne	(E)	Oct. 1890
Stirling, Andrew, Jun., 1, Greenvale Terrace, Dumbarton... ...	(E)	Feb. 1888
Stirzaker, J. C., 16, Grosvenor Place, Newcastle-upon-Tyne ...	(E)	Nov. 1884
Stoddart, J. E., Lloyd's Register of Shipping, White Lion Court, Cornhill, London, E.C.	(E SUR)	Oct. 1888
Stoddart, Swinton, 24, North Milburn Street, Sunderland (S)	Graduate,	May 1885
	Member,	Nov. 1892
Stokoe, Thomas W., 55, Northcote Street, South Shields	(S)	Dec. 1885
Stroughair, John W. H., 93, Meldon Terrace, Heaton, Newcastle-upon-Tyne	(E)	Nov. 1894
Summers, James, 114, Grange Road West, Middlesbrough ...	(E)	Mar. 1889
Surtees, Francis V., Westfield, Renfrew	(S)	Dec. 1892
Surtees, R., Frame House, Low Teams, Gateshead-on-Tyne ...	(E)	Nov. 1884
Swan, A. S., Grove House, Gosforth, Newcastle-upon-Tyne ...	(S)	Nov. 1888
Swan, Charles Sheriton, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne... ... ... (S)	Graduate,	Nov. 1890
	Member,	Mar 1894
Swan, H. F., North Jesmond, Newcastle-upon-Tyne	(S)	Nov [illegible]
Swinburne, M. W., 117, Park Road, Newcastle-upon-Tyne ...	(E)	No[illegible]
Swinburne, T. M., Bewick Road, Gateshead-on-Tyne	(E)	Jar[illegible]
Swinney, W., 10, Wentworth Terrace, Westoe Lane, South Shields	(E)	Dec [illegible]
Sydserff, Thomas B., Jun., 2, Claremont Villas, Totterdown, Bristol	(E)	Oct [illegible]
Syme, James, Fairfield Works, Govan, Glasgow	(E)	Oc[illegible]

T.

ELECTED.

Tate, Chas. H., 7, Side, Newcastle-upon-Tyne ... ... (N A) Nov. 1884
Taylor, Alexander, Maritime Buildings, King Street, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Taylor, John, 1, St. Alban's Place, Tynemouth ... ... (E) Dec. 1894
Taylor, J. W. H. Maxwell, 5, East Parade, Newcastle-upon-Tyne (E) Feb. 1898
Teasdale, John, 13, Wandsworth Road, Newcastle-upon-Tyne ... (E) Mar. 1898
Thompson, Arthur E., 19, The Crescent, Gateshead-on-Tyne ... (E) May 1898
Thompson, Charles, M.A., 33, Mosley Street, Newcastle-upon-Tyne (E) Feb. 1887
Thompson, C. E., Messrs. J. L. Thompson & Sons, North Sands, Sunderland... ... ... (S) Nov. 1884
Thompson, Chas. Henry, 36, Carlton Street, West Hartlepool .. (S) Feb. 1898
Thompson, Jas., 2, Carlton Terrace, Sunderland ... ... (E) Dec. 1886
Thompson, John Augustus, 12, London Street, Fenchurch Street, London, E.C. ... ... (E & N A) Oct. 1892
Thompson, J. L., North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thompson, Robert, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thomson, James, M.A., c/o Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd., Ordnance Works, Elswick, Newcastle-upon-Tyne ... ... (E & N A) Nov. 1890
Thorn, W. H., 5, Waterville Terrace, North Shields ... ... (E) Nov. 1884
Thornton, James, 4, Croft Villas, Jarrow-on-Tyne ... ... (E) April 1893
Thornton, Thomas Lee, 45, Northcote Street, Newcastle-upon-Tyne (E) Feb. 1898
Tinn, Fred. D., 2, Sunningdale Terrace, South Shields ... ... (E) Nov. 1891
Tinn, George, 205, Cardigan Terrace, Gateshead-on-Tyne... ... (E) Dec. 1897
Tocher, J. W., c/o Messrs. Wallsend Slipway and Engineering Co. Co., Wallsend-on-Tyne ... ... (S) Mar. 1898
Todd, John P., 13, Chatsworth Street, Sunderland ... ... (E) Dec. 1897
Toovey, Alfred F., Ovington Cottage, Prudhoe, Northumberland (E) Dec. 1894
Towers, Edward, Jun., 4, Latimer Street, Tynemouth (E) {Graduate, Nov. 1886 / Member, Oct. 1888}
Trail, John, 21, Grosvenor Place, Jesmond, Newcastle-upon-Tyne (M S) Oct. 1892
Traill, Robert, 8, Newcastle Street, North Shields ... ... (E) Oct. 1896
Trechmann, J. E., c/o Messrs. Otto Trechmann, Ltd., West Hartlepool ... ... (E) Feb. 1898
Trewent, F. J., 43, Billiter Buildings, Billiter Street, London, E.C. ... ... (S) Dec. 1884
Trowell, Wm. John, Board of Trade Surveyor's Offices, Custom House, Arcade, Liverpool ... ... (E) Oct. 1894
Turner, S. J., 71, Warwick Street, Heaton, Newcastle-upon-Tyne (E) Mar. 1887
Turpie, David Whyte, c/o Messrs. W. Pickersgill & Sons, Southwick, Sunderland ... ... (S) Dec. 1895
Tuxen, Holger, Bureau Veritas Register of Shipping, Custom House Court, Quayside, Newcastle-upon-Tyne ... ... (S) Nov. 1896
Twaddell, James L., 4, St. John's Terrace, Jarrow-on-Tyne ... (S) Oct. 1891
Tweedy, J., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884
Twigden, George J., c/o Messrs. Hick Bros., 37, Mount Stuart Square, Cardiff ... ... (E) Jan. 1890
Tyzack, George, Dean Street, South Shields... ... ... (E) April 1888

U.

ELECTED.

Ullstrom, Otto, 84, Leadenhall Street, London, E.C. ... ... (S) Nov. 1884
Ulm, John, The Arsenal, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *vid* Corsica 20/5, Genoa, Italy ... ... (E) Dec. 1885
Vick, R. W., Messrs. Furness, Withy & Co., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1888
Vivet, Leon, 25, Rue de Pornichet, St. Nazaire, France ... ... (N A) Nov. 1892

W.

Wadagaki, Yasuzo, Union Ironworks, San Francisco, California ... (E) Jan. 1891
Wait, Thomas Herbert, Cail's Buildings, Quayside, Newcastle-upon-Tyne ... ...(C E) Dec. 1893
Wake, Tom, 2, Cliff Terrace, Hartlepool ... ... (E) April 1892
Wakeham, John F., 38, King John Street, Heaton, Newcastle-upon-Tyne ... ... (S) { Graduate, Mar. 1893; Member, Oct. 1895
Walker, Archibald, 143, Leith Walk, Leith, N.B. ... ... (E) April 1887
Walker, Charles J., Elswick Works, Newcastle-upon-Tyne ... (E) Jan. 1898
Walker, Henry, 11, Oxford Terrace, Gateshead-on-Tyne ... ... (E E) Feb. 1893
Walker, John, c/o Messrs. R. Stephenson & Co., Limited, South Street, Newcastle-upon-Tyne ... ... (E & S) Nov. 1891
Wallau, J., 68, Coatsworth Road, Gateshead-on-Tyne ... ... (E) Nov. 1884
Waller, Thomas Naunton, 10, Holly Avenue, Jesmond, Newcastle-upon-Tyne ... . (E) May 1898
Walliker, J. F., Lloyd's Register of Shipping, Bute Docks, Cardiff (E) Nov. 1885
Walliker, John George, c/o Messrs. Hodges & Walliker, Barry Docks, South Wales ... ... (E) May 1896
Wallis, Robert, Wh.Sc., Point Pleasant House, Wallsend-on-Tyne (E) April 1891
Walter, Max, Norddeutscher Lloyd, Central Bureau, Bremen ... (S) Feb. 1893
Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884
Walton, Samuel, 34, Pollard Street, South Shields ... ... (E) Dec. 1893
Warburton, J., 4, Beauclerc Terrace, Sunderland ... ... (S) Nov. 1884
Warburton, John Arthur, 47, Harrogate Street, Sunderland (E) { Graduate, Mar. 1894; Member, Nov. 1896
Ward, John, c/o Messrs. W. Denny & Bros., Dumbarton ... ... (S) Dec. 1891
Ward, Mark W., 95, West Percy Street, North Shields ... ... (E) Dec. 1893
Wardale, Henry, 5, Collingwood Terrace, Gateshead-on-Tyne ... (E) Feb. 1888
Warden, Thomas M., 21, Windermere Street, Gateshead-on-Tyne (E) Oct. 1894
Watson, Thomas Henry, 10, Neville Street, Newcastle-upon-Tyne (SUR) Jan. 1896
Watts, Philip, Elswick Shipyard, Newcastle-upon-Tyne ... ... (S) Nov. 1885
Wedgwood, Josiah, c/o Messrs. Armstrong, Whitworth, & Co., Elswick Shipyard, Newcastle-upon-Tyne ... ... (N A) Nov. 1897
Weidemann, Nils, Det-Norske Veritas, Christiania, Norway ...(SUR) Jan. 1892
Weighton, R. L., M.A., Durham College of Science, Barras Bridge, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Weir, George Dobie, Northumberland Engine Works, Wallsend-on-Tyne ... ... (E) Oct. 1894

ELECTED.

Weir, John, c/o Messrs. J. Scott & Co., Abden Works, Kinghorn, N.B. ... ... (E) Nov. 1884
Weir, William, c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne ... ... (E) Nov. 1889
Welton, J. G., 12, Hendon Valley Road, Sunderland ... ... (E) Nov. 1893
West, Henry H., British and Foreign Chambers, 5, Castle Street, Liverpool ... ... (E & N A) Oct. 1886
Westgarth, Tom, Messrs. Sir C. Furness, Westgarth, & Co., Middlesbrough ... ... (E) Oct. 1886
Westmacott, Alfred, Benwell Hill, Newcastle-upon-Tyne (E) { Graduate, Dec. 1885 / Member, Nov. 1892
Westmacott, P. G. B., Benwell Hill, Newcastle-upon-Tyne ... (E) Nov. 1884
Wheater, Chas. Busfield, 14, York Street, Newcastle-upon-Tyne... (E) Oct. 1894
White, C., 13, Mosley Street, Newcastle-upon-Tyne ... ... (E) Nov. 1884
White, Ernest T., 1, Camborne Place, Gateshead-on-Tyne (E) { Graduate, May 1889 / Member, Jan. 1894
White, R. Saxon, Messrs. Sir W. G Armstrong, Whitworth, & Co., Ltd., Walker Shipyard, Walker-on-Tyne ... ... (S) Nov. 1884
Whitfield, Thomas, Messrs. Tyne Dock Engineering Co., South Shields ... ... (E) April 1896
Whittaker, Frederick W., Dockyard, Coburg Dock, Messrs. Mersey Docks and Harbour Board, Liverpool ... ... (E) Oct. 1892
Whyte, Wm., B, Lombard Street, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Widdas, T. D., 56, Plasturton Avenue, Cardiff ... ... (SUR) April 1885
Wilkie, J., 24, Camden Street, Southwick, Sunderland ... ... (E) Nov. 1884
Willcox, Henry Walker, 68, John Street, Sunderland ... ... (C E) Nov. 1897
Willcox, Percy F. C., 68, John Street, Sunderland ... ... (C E) Nov. 1897
Willcox, R. J. N., c/o Mrs. Stafford, 15, Lennox Street, Middlesbrough ... ... (E) { Graduate, Mar. 1892 / Member, Dec. 1897
Williams, Thomas R., Chantiers, Navals de Nicolaieff a Bouffioulx, Chatelineau (Hainaut), Belgique ... ... (S) Oct. 1895
Wilson, Alfred C., B.Sc., 1, Bank Terrace, Wallsend-on-Tyne ... (E) Feb. 1898
Wilson, Henry J. H., 117, Bede Burn Road, Jarrow-on-Tyne ... (E) Nov. 1895
Wilson, James, Messrs. T. Richardson & Sons, Hartlepool Engine Works, Hartlepool ... ... (E) Jan. 1896
Wilson, John Paul, Messrs. Palmer's Shipbuilding Co., Jarrow-on-Tyne... ... ... (S) Oct. 1895
Wimble, Arthur, c/o Messrs. Boyd & Co., Limited, Shanghai, China (E) Dec. 1893
Winstanley, P. D., Bureau Veritas Register of Shipping, 155, Fenchurch Street, London ... ... (S) Nov. 1884
Winter, Thor., Aktiebolaget Sandvikens Skeppsdocka och mekaniska verkstad, Helsingfors, Finland ... ... (E) Nov. 1893
Withy, H., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1884
Wood, Henry Alfred, Oakfield Road, North Ormesby, Middlesbrough-on-Tees ... ... (S) Dec. 1893
Wood, John Scott, 6, Eslington Terrace, Newcastle-upon-Tyne ... ... (S) { Graduate, Oct. 1891 / Member, Oct. 1896
Wood, Joseph, Foundry Manager, Deptford Yard Brass Works, Sunderland... ... ... (E) Mar. 1895
Wood, William, 6, Eslington Terrace, Newcastle-upon-Tyne ... (S) Nov. 1897
Wortley, Henry B., 23, Bedford Road, Rock Ferry, Birkenhead ... ... (S) { Graduate, Jan. 1886 / Member, Nov. 1892

ELECTED.

Wray, Thomas W., Board of Trade Offices, Sunderland ... ...(SUR) Jan. 1895
Wright, R., 5, Hawthorn Terrace, Newcastle-upon-Tyne ... ... (E) Nov. 1884
Wright, William Charles, Lynnfield, Norton, Stockton-on-Tees ... (E) Feb. 1898
Wyand, Frederick W., 13, Eldon Street, Newcastle-upon-Tyne ... ... (E E) { Graduate, Oct. 1894 / Member, Jan. 1898

Y.

Young, Andrew, Bureau Veritas Register of Shipping, 155, Fenchurch Street, London, E.C. ... ... (S) { Graduate, Feb. 1892 / Member, May 1893
Young, J. Denholm, 2A, Tower Chambers, Liverpool ... ... (E) Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-upon-Tyne ... (E) Nov. 1884

Z.

Zeeman, J. H., 5, Willemsplein, Rotterdam ... ... (S) Oct. 1889

ASSOCIATES.

A.

Anderson, Daniel G., c/o Messrs. W. Angus & Co., Grainger Street West, Newcastle-upon-Tyne ... ... (A) Nov. 1893
Armstrong, S., Beaconsfield Street, Hartlepool ... ... (A) Nov. 1888
Arnott, James, 25, Dean Street, Newcastle-upon-Tyne ... ...(S O) Oct. 1895

B.

Bacon, William Charles, Chadwick House, West Hartlepool ...(S O) Dec. 1890
Ball, Alfred F., 14, Landsdowne Terrace, Gosforth, Newcastle-upon-Tyne ... ... (A) Nov. 1894
Barklam, George, 167, Dudley Port, Tipton, Staffordshire ... (A) April 1888
Barr, John Smith, 16, Broad Chare, Quayside, Newcastle-upon-Tyne... ... ... (A) Nov. 1893
Barwick, J. S., Ashbrook Grange, Sunderland ... ...(S O) Nov. 1884
Bell, Alfred, 11, Osborne Terrace, Newcastle-upon-Tyne ... (S O) Nov. 1897
Bell, J. H., Netherhall, Lenzie, Dumbartonshire ... ... (I & S M) Oct. 1887
Beynon, Thomas, 9, Dean Street, Newcastle-upon-Tyne ... ... (E A) Oct. 1891
Bigge, C. W., Northern Counties Club, Newcastle-upon-Tyne ... (A) Dec. 1889
Bingham, Col. J. E., Manufacturer, West Lea, Sheffield ... ... (M) Mar. 1895
Bird, William, 8, Latimer Street, Tynemouth ... ... (A) May 1896
Blacklin, Richard James, Dinsdale House, Brougham Terrace, West Hartlepool ... ...(S O) Dec. 1890
Briggs, R. S., Moorlands, Sunderland ... ...(S O) Dec. 1886
Brims, D. N., 4, St. Nicholas' Buildings, Newcastle-upon-Tyne ... (C) Nov. 1893
Brown, Percy Ledger, 1, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (E A) Oct. 1896
Brunton, John, 3, Prior's Terrace, Tynemouth ... ...(S O) Oct. 1886
Bullen, Tempest C., c/o Messrs. H. E. Moss & Co., K, Exchange Buildings, Newcastle-upon-Tyne ... ...(S O) Nov. 1891

C.

ELECTED.

Caminos, T. L., Overseer, Argentine Navy, 47, Chester Street, Birkenhead... ... ... June 1896
Carr, Ralph, Thornleigh, Clayton Road, Newcastle-upon-Tyne (A & S O) Nov. 1886
Cassap, William, 15, East Field Road, Walthamstow, Essex ...(SUR) Feb. 1890
Caws, Frank, 22, Fawcett Street, Sunderland ... ...(C E) Oct. 1892
Cay, Arthur, Messrs. Cay, Hall, & Co., Queen Street, Newcastle-upon-Tyne ... ...(S O) Nov. 1884
Coates, Henry, Hamburg Chambers, Newcastle-upon-Tyne ...(SUR) Nov. 1897
Cohan, Edward Asher, 2, Rumford Place, Liverpool ... ...(S O) Nov. 1889
Cooper, Charles, Average Adjuster, Wellington Road, West Hartlepool ... ...(A A) April 1893
Corbitt, Michael, Springfield, Gateshead-on-Tyne ... ...(R M) Jan. 1890
Cory, John, Cardiff ... ...(S O) June 1896
Coull, John, Baltic Chambers, Quayside, Newcastle-upon-Tyne ...(S O) Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool ... ...(S O) Nov. 1888
Craik, A., Messrs. Blyth Dry Dock, Limited, Blyth ... ... (A) June 1896
Crawford, Thomas, 10, Haldane Terrace, West Jesmond, Newcastle-upon-Tyne ... ... (A) Oct. 1896
Crosier, Edward James, 3, The Hawthorns, East Boldon ... ... (A) Oct. 1889
Culliford, J. H. W., 45, West Sunniside, Sunderland ... ...(S O) Nov. 1884

D.

Dodds, E. F., 36, Side, Newcastle-upon-Tyne ... ... (A) Nov. 1893
Dodds, John B., 36, Side, Newcastle-upon-Tyne ... ... (CHEM) Oct. 1888
Donkin, Geo., Jun., 50, Grove Street, Newcastle-upon-Tyne ... (A) April 1897
Dove, Edward John, 5, St. Nicholas' Buildings, Newcastle-upon-Tyne ... ... (M) Oct. 1890

E.

Eccles, Edward, Royal Insurance Buildings, Queen Street, Newcastle-upon-Tyne (*Life Associate*) ... ...(S O) Oct. 1887

F.

France, James A., St. John Street, Newcastle-upon-Tyne ... (M) Jan. 1898
Frazer, Joseph S., Britannia Buildings, Cardiff ... ... (M) June 1896
Furness, Sir Christopher, Baltic Chambers, West Hartlepool ...(S O) Oct. 1888

G.

Graham, Frank, Bank Chambers, Mosley Street, Newcastle-upon-Tyne ... ...(E A) Nov. 1891

H.

Hardy, John, Jun., Brunswick Street, West Hartlepool ... ...(I M) Nov. 1893
Harland, George, 1, Westoe Crescent, South Shields ... ... (A) Dec. 1888
Harrison, Samuel Turner, The Green, Wallsend ... ... (A) Nov. 1897

ELECTED.

Harrison, Thomas, 9, Bridge Street, Sunderland ... ... (A) Dec. 1894
Hedley, John H., 10, Esplanade West, Sunderland... ... ... (S) Dec. 1886
Henzell, Robert, 43, Sanderson Road, Newcastle-upon-Tyne (*Life Associate*) ... ... (A) Nov. 1893
Heslop, Richard O., Akenside Hill, Newcastle-upon-Tyne... (I & S M) Oct. 1885
Hodge, W. P., c/o Messrs. John Cory & Sons, Mount Stuart Square, Cardiff ... ...(M S) Mar. 1896
Hogg, John Thomas, Tyneside Brass Works, Barry Docks, South Wales ... ... (I & S M) April 1896
Holliday, Henry, Beechgrove, Blackhill, Co. Durham ... ... (A) Nov. 1895
Hollis, H. E., 40, Union Street, Glasgow ... ... (I & S M) Feb. 1885
Hudson, Ralph M., Jun., 8, The Cedars, Sunderland ... ... (S O) Dec. 1886
Hudson, Robert, 24, Hotspur Street, Tynemouth ... ... (A) Nov. 1895
Hunting, Charles S., 1, Exchange Buildings, Quayside, Newcastle-upon-Tyne ... ...(S O) April 1886
Hurndall, Sidney E., Printing Court Chambers, Newcastle-upon-Tyne... ... ... (A) Nov. 1893

I.

Innes, Charles H., Rutherford College, Newcastle-upon-Tyne ... (E) Oct. 1891

J.

Jenkins, Alfred, c/o Messrs. The Mercantile Dry Dock Co., Jarrow-on-Tyne ... ... (A) Nov. 1893
Jobson, W. J., c/o Messrs. Robert Stephenson & Co., South Street, Newcastle-upon-Tyne ... ... (A) May 1889
Jordan, John George, 24, Stansfield Street, Sunderland ... ... (A) Nov. 1892

K.

Kemp, James, Baltic Chambers, Newcastle-upon-Tyne ... ...(S O) Feb. 1896
Knott, James, Prudential Buildings, Newcastle-upon-Tyne ... (S O) Dec. 1896

L.

Lloyd, John, Deptford Shipyard, Sunderland ... ... (A) Oct. 1894
Lockie, John, Bank Chambers, Sandhill, Newcastle-upon-Tyne ... (S O) Oct. 1892
Lodwidge, Philip, Baltic Chambers, Sunderland ... ... (A) June 1896

M.

Macarthy, George E., 9, Dean Street, Newcastle-upon-Tyne ...(S O) Oct. 1887
Mail, Douglas B., 14, Humbleton View, Sunderland ... ...(M S) Feb. 1895
Maughan, William, 13, Mosley Street, Newcastle-upon-Tyne ... (A) Feb. 1887
McIntosh, R. Y., 34, Dean Street, Newcastle-upon-Tyne ... ... (E A) Nov. 1891
McIntyre, John, 3, Abbotsford Terrace, Newcastle-upon-Tyne ... (S O) Jan. 1885
Meek, John George, 13, Belle Vue Park, Sunderland .. ... (A) Dec. 1894
Milburn, J. D., Queen Street, Newcastle-upon-Tyne ... ... (S O) Nov. 1884
Miller, T. R., 9, Great St. Helen's, London, E.C. ... ... (A & S O) Nov. 1884
Mitcalfe, John Stanley, Chairman of Northern Maritime Insurance Co., Maritime Buildings, Newcastle-upon-Tyne ... (A & S O) Jan. 1892

ELECTED.

Morton, Benjamin, 18, St. George's Square, Sunderland ... ...(SUP) Dec. 1895
Muir, James, 2, Dingle Lane, Liverpool ... ...(M S) Nov. 1893
Mulherion, G. F., 3, Rothbury Terrace, Heaton, Newcastle-upon-Tyne ... ... (A) Nov. 1884
Muller, J. C. F., 28, Vieille Route, Antwerp ... ...(SUR) Feb. 1890
Murray, Matthew, The Green, Wallsend-on-Tyne ... ... (A) Nov. 1893

N.

Neilsen, Hans Christian, 12, Cliff Terrace, Hartlepool ... ... (S O) Feb. 1898
Nicholson, John, 7, Side, Newcastle-upon-Tyne ... ... (M S) Nov. 1890
Nixon, John, c/o Messrs. Blyth Shipbuilding Co., Blyth ... ... (A) Oct. 1894

O.

O'Hagan, James, 99, Quai de la Fosse, Nantes, France ... ... (A) Oct. 1888
Olsen, Hans Benedick, 70, Church Street, West Hartlepool ... (S O) Mar. 1893
Osbourne, Jas., 11, The Oaks, Sunderland ... ... (S) Jan. 1885

P.

Park, Robert, Lauriston, Blackhill, Co. Durham ... ... (A) Dec. 1897
Patterson, Thos., 2, The Elms, Sunderland ... ... (S) Jan. 1885
Petersen, Ferd. William, Messrs. Petersen & Tate, Bank Chambers, Sandhill, Newcastle-upon-Tyne ... ... (S O) Nov. 1893
Phalp, Oliver, Almora, 37, Richmond Road, Cardiff ... ...(SUR) Feb. 1889
Pinkney, Thomas, 3, Ashbrook Terrace, Sunderland ... ...(S O) Dec. 1886
Proctor, J. H., 22, Hawthorn Terrace, Newcastle-upon-Tyne ... (I M) Nov. 1893

R.

Radloff, Captain O., c/o Messrs. Russian Steam Navigation Co., Odessa ... ... (M S) Nov. 1891
Raine, John, Baltic Chambers, Sunderland ... ... (S O) Nov. 1897
Ramsay, J. W., 13, Northbrook Road, Lee, Kent ... ... (A) Feb. 1885
Reichwald, A., Lombard Street, Newcastle-upon-Tyne ... ... (A) Nov. 1884
Reid, Sidney, Printer, Akenside Hill, Newcastle-upon-Tyne ... Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Maritime Buildings, King Street, Newcastle-upon-Tyne ... ... (S O) Nov. 1884
Riddle, John C., c/o Messrs. Walker & Hall, 8, Gordon Street, Glasgow ... ... (A) May 1896
Robson, Frederick, 46, Dean Street, Newcastle-upon-Tyne (S I M) Oct. 1887
Robson, John William, G, King Street, Newcastle-upon-Tyne ... (M) April 1896
Robson, Thos., Causeway House, Sunderland ... ...(S O) Nov. 1884
Runciman, Walter, Fernwood House, Clayton Road, Newcastle-upon-Tyne ... ...(S O) May 1895

S.

Scholefield, A., 17, Sandhill, Newcastle-upon-Tyne ... ...(S O) Nov. 1884
Scott, W. H., Messrs. Scott Brothers, 46, Sandhill, Newcastle-upon-Tyne... ... ...(S O) Nov. 1884
Snowdon, W. F., 2, Side, Newcastle-upon-Tyne ... ... (E A) Dec. 1886

ELECTED.

Squance, J. W., 13, The Avenue, Sunderland ... ... (M S) April 1888
Storey, Christopher, 28, Holly Avenue, Jesmond, Newcastle-upon-Tyne... ... ... (A) April 1896
Sutherland, Arthur M., 7, Collingwood Terrace, Newcastle-upon-Tyne ... ... (S O) Nov. 1897
Swan, Isaac J., Grove House, Gosforth, Newcastle-upon-Tyne ... (S O) Feb. 1888

T.

Tate, Arthur, Messrs. Petersen & Tate, Bank Chambers, Sandhill, Newcastle-upon-Tyne ... ... (O) Nov. 1893
Thompson, V. T., Baltic Chambers, Sunderland ... ...(S O) Dec. 1886
Todd, John Stanley, Percy Park, Tynemouth ... ... (U) Nov. 1895
Towers, Edward, 4, Latimer Street, Tynemouth ... ... (A) Oct. 1888
Trechmann, Otto K., Church Street, West Hartlepool ... ... (S O) Oct. 1896
Turner, Edwin, 32, Powell Road, Clapton, London, N.E. ... ... (A) Oct. 1895

W.

Wait, James, Maritime Buildings, King Street, Newcastle-upon-Tyne... ... ...(S O) Nov. 1884
Walker, James, 87, Jesmond Road, Newcastle-upon-Tyne... ... (S O) Mar. 1894
Watson, Thomas W., Gisburn House, Hartlepool ... ... (M S) Nov. 1890
Weatheral, Henry, 27, Alderson Street, West Hartlepool ... ... (A) Feb. 1893
Whitfield, John, Blyth ... ... (S) Nov. 1895
Wight, Robert M., 42, The Exchange, Cardiff ... ... (M) June 1896
Wilson, F. Alfred, 45, West Sunniside, Sunderland ... ... (I M) Nov. 1893
Winstanley, Robt. Hope, 8, Kenilworth Road, Newcastle-upon-Tyne (A) Nov. 1897
Winter, Edward G., 10, Lincoln Terrace, Gateshead-upon-Tyne ... (A) May 1898

Y.

Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool ... (S O) Nov. 1888
Younger, Robert Laurie, Messrs. Greenock Steamship Co., Limited, Greenock ... ... (A) Feb. 1889

GRADUATES.

A.

Adams, Jas. Wilson, 8, Belle Vue Terrace, Gateshead-on-Tyne ... (E E) Nov. 1897
Adamson, Charles P., High Street, Yarm-on-Tees ... ... (E) Nov. 1897
Andrew, David, Jun., 33, Osborne Road, Newcastle-upon-Tyne ... (E) Oct. 1891
Andrew, John Davis, 33, Osborne Road, Newcastle-upon-Tyne ... (E) Jan. 1898

B.

Barbour, John, 1, Logan Terrace, South Shields ... ... (E) Nov. 1890
Beilby, Norman Harry, 1, Kingsley Place, Heaton, Newcastle-upon-Tyne ... ... (E) Dec. 1893

ELECTED.

Bentham, Frederick Lister, 9, Bellegrove Terrace, Newcastle-upon-Tyne ... ... (E) Dec. 1892
Binns, Aubrey B., 23, Thornhill Terrace, Sunderland ... ... (E) Oct. 1894
Bocler, Harry, 20, Briery Vale Road, Sunderland ... ... (N A) Mar. 1898
Bolam, J. H., 46, Northumberland Street, Newcastle-upon-Tyne... (E) Nov. 1897
Borthwick, Robert J., 8, Kensington Terrace, Newcastle-upon-Tyne... ... ... (E) Dec. 1894
Boswell, Cecil Robert, Frances Villa, Highfield Road, Dartford ... (E) Nov. 1893
Bowden, John, Sheriff Mount, Gateshead-on-Tyne ... ... (E) Jan. 1894
Brigham, Malcolm, Westoe Tower, South Shields ... ... (E) Mar. 1898
Brown, Thomas Scott, Jun., 18, Nixon Street, Newcastle-upon-Tyne ... ... (E) Oct. 1895
Buchanan, Samuel, Jun., 51, Welbeck Road, Walker-on-Tyne ... (S) Feb. 1897
Bulmer, Albert Edward, 1, Graingerville North, Newcastle-upon-Tyne... ... ... (E) Nov. 1895
Bulmer, Septimus, 1, Graingerville North, Newcastle-upon-Tyne (E) May 1894
Burbidge, Alfred H., 15, North View, Heaton, Newcastle-upon-Tyne... ... ... (E) Oct. 1895
Burn, Donald B., 7, The Elms West, Sunderland ... ... (S) Nov. 1893

C.

Canning, Chas. E., 31, Park Crescent, North Shields ... ... (S) Dec. 1897
Carpmael, Richard Herbert, Ordnance Department, Elswick Works, Newcastle-upon-Tyne ... ... (E) Jan. 1893
Carr, Ralph, Jun., Thornleigh, Clayton Road, Newcastle-upon-Tyne (E) Jan. 1894
Carter, Thomas, 6, Larkspur Terrace, Newcastle-upon-Tyne ... (E E) Oct. 1895
Chapman, John Frederick, 70, Lovaine Place, Newcastle-upon-Tyne (E E) Dec. 1895
Coatsworth, George S., Oaks West, Sunderland ... ... (E) Nov. 1891
Coulson, Richard H. A., 12, East View, South Shields ... ... (E) April 1897
Craggs, Adolphus, Ivy House, Pelton, Chester-le-Street ... ... (E) Dec. 1897
Crawford, J. F., "Palmyra," St. George's Road, Waterloo, near Liverpool ... ... (E) Nov. 1893
Crombie, W. Alan D., Park House, North Berwick... ... ... (E E) Oct. 1894
Currie, Hugh B., 41, Eldon Street, Newcastle-upon-Tyne... ... (E) Nov. 1897

D.

Dalziel, E., 97, Sandyford Road, Newcastle-upon-Tyne ... ... (E) Feb. 1898
Davison, William H. G., 17, Lovaine Place, Newcastle-upon-Tyne (E) Dec. 1892
Dickie, James, Jun., 18, Brinkburn Terrace, Westoe South Shields (S) Mar. 1898
Dickie, John P., 18, Brinkburn Terrace, Westoe, South Shields ... (E) Mar. 1898
Dixon, John Wm., 7, Belle Vue Terrace, Gateshead-on-Tyne ... (E) Nov. 1897
Dixon, William John, H.M.S. "Renown," North American Station ... ... (E) Mar. 1896
Dobson, William Gordon, The Chesters, Jesmond, Newcastle-upon-Tyne... ... ... (S) Feb. 1896
Dodds, John Hanbury, National Provincial Bank, Redcar ... (E) Feb. 1896
Donaldson, Henry B., 10, Lily Crescent, Jesmond West, Newcastle-upon-Tyne ... ... (S) Nov. 1897

ELECTED.

Doxford, Robert, Jun., Silksworth Hall, Sunderland ... ... (N A) Feb. 1897
Duckitt, Talbot, 56, Leicester Road, Loughborough... ... ... (E E) Oct. 1891
Dunford, Thomas, 74, Osborne Road, Newcastle-upon-Tyne ... (E) Nov. 1896

E.

Edminston, Alex. R., c/o Mrs. Sheffield, 10, Beaconsfield Square, Hartlepool ... ... (E) Jan. 1898

F.

Featherstonhaugh, Albany, 13, Park Place West, Sunderland ... (E) Oct. 1894
Fenton, Frederick, 15, Kent Street, Jarrow-on-Tyne ... ... (S) Mar. 1898
Fleet, Herbert A., Coney House, Birtley, *via* Chester-le-Street ... (E) Mar. 1897
Forster, Edgar S., Grange Villa, Lawford Gardens, Rugby ... (E) Jan. 1894
Foster, L. P., 23, Lovaine Crescent, Newcastle-upon-Tyne ... (E) Nov. 1893
Fox, Carter, 7, Coxon Street, Sunderland ... ... (E) Feb. 1898

H.

Hamilton, James, Messrs. The Royal Shipbuilding and Engineering Co., Flushing, Holland ... ... (E) Nov. 1897
Harden, G. F. St. Clair, 6, Larkspur Terrace, Jesmond, Newcastle-upon-Tyne ... ... (E) Feb. 1898
Harvey, Herbert B., Roker Villa, Heaton Park View, Heaton, Newcastle-upon-Tyne ... ... (E) Jan. 1896
Hepburn, James M., 17, Grosvenor Place, Jesmond, Newcastle-upon-Tyne ... ... (E) Nov. 1895
Hick, Charles, 2, Garibaldi Terrace, South Shields ... ... (E) Oct. 1894
Hinchliffe, Robert, 25, Hawthorn Street, Newcastle-upon-Tyne ... (S) Nov. 1893
Hobbs, Arthur, 134, Coalshaw Green Road, Hollinwood, Oldham (E) Nov. 1897
Hunter, George Ernest, The Willows, Jesmond, Newcastle-upon-Tyne ... ... (S) Feb. 1898
Hutton, John S., 17, Claremont Place, Newcastle-upon-Tyne ... (E) Nov. 1897

J.

Jepson, Henry, 35, Elvet Street, Heaton, Newcastle-upon-Tyne ... (E) Nov. 1893
Johnson, James, 11, Poplar Crescent, Gateshead-on-Tyne ... ... (E) Oct. 1896

K.

Kent, Samuel N., Lindenhurst, Heaton, Newcastle-upon-Tyne ... (E) Mar. 1896

L.

Laing, Bryan, Thornhill, Sunderland... ... ... (S) Dec. 1895
Leighton, James, 17, Eversley Place, Heaton, Newcastle-upon-Tyne ... ... (E) Jan. 1896
Lindsay, James D., Fernville, Gosforth, Newcastle-upon-Tyne ... (E E) Jan. 1897
Lishman, John James, Jun., 16, Lovaine Place, North Shields ... (E) Dec. 1892

ELECTED.

London, W. J. A., 12, Victoria Square, Jesmond, Newcastle-upon-Tyne ... ... (E) May 1898
Lumley, William, 2, Claremont, Gateshead-on-Tyne ... ... (E) June 1896

M.

Macdonald, William C., 15, Union Street, Hartlepool ... ... (E) Mar. 1895
Mace, Charles, c/o Messrs. Laird Brothers, Birkenhead ... ... (E) Nov. 1894
Mace, George, 253, Albert Road, Jarrow-on-Tyne ... ... (S) Oct. 1896
Mather, Clifford B., Lesbury House, Lesbury, R.S.O., Northumberland ... ... (S) Oct. 1892
McCoull, Cecil, Ovington House, Ovingham, R.S.O., Northumberland .. .. (E) Oct. 1895
McIlwraith, Charles H. C., 37, Woodbine Terrace, Pallion, Sunderland (E) Nov. 1895
McRobie, Frank, 20, Victoria Street, Newcastle-upon-Tyne ... (E) Mar. 1889
Milne, George Murray, 17, East Percy Street, North Shields ... (S) Feb. 1898
Mitchell, William, Glen Street, Hebburn-on-Tyne ... ... (S) Jan. 1898
Moore, Jas. Forster, 6, Princess Street, Sunderland ... ... (E E) Nov. 1897
Moroney, Edward F., 180, Gloucester Road, Newcastle-upon-Tyne (E) Feb. 1892
Moss, William, Point Pleasant Hall, Wallsend-on-Tyne ... ... (E) Jan. 1898
Murray, Athole J., Hassendean, Beech Grove, Newcastle-upon-Tyne ... ... (S) Nov. 1897

N.

Nixon, John Robert, 4, Bath Terrace, Blyth ... ... (E) Feb. 1898

O.

Olsen, Hans B., Jun., Wellington Road, West Hartlepool... ... (E) Feb. 1895

P.

Pashby, Arthur, 18, Ashfield Terrace East, Newcastle-upon-Tyne... (E) Nov. 1895
Patterson, Robt. O., Thorneyholme, Blaydon-on-Tyne ... ... (E) Jan. 1895
Pearce, Standen L., Hampden Club, Phœnix Street, London, N.W. (E) Dec. 1893
Pescod, Joseph Hind, 1, Railway Street, Jarrow-on-Tyne ... (S) Feb. 1898
Pierce, Robert Cecil, 4, Simonside Terrace Heaton, Newcastle-upon-Tyne ... ... (E E) Dec. 1896
Posgate, James Stephen, 11, Wandsworth Road, Heaton, Newcastle-upon-Tyne ... ... (E) Nov. 1895
Potts, Joseph, 14, Moreland Street, West Hartlepool ... ... (E) Feb. 1898

R.

Rappoport, Fred. G., 33, Manor House Road, Jesmond, Newcastle-upon-Tyne ... ... (E) Mar. 1894
Reid, John Robert, 88, Leslie Terrace, Aberdeen ... ... (E) Nov. 1892
Robinson, Charles O., Ingleside, North Shields ... ... (E) Dec. 1893
Robinson, Francis, Willington Rectory, Newcastle-upon-Tyne ... (E) Nov. 1897
Robson, Robert, 166, Rye Hill, Newcastle-upon-Tyne ... ... (E E) Dec. 1894

ELECTED.

Ross, William Daniel, 11, Alma Street, Sandyford Road, Newcastle-upon-Tyne ... ... (E) Feb. 1896
Routledge, Herbert J., Stapleton House, Jarrow-on-Tyne ... (E E) Mar. 1897
Rowles, Henry P., 8, Belle Vue Terrace, Gateshead-on-Tyne ... (E) Oct. 1896
Ruhaak, G. H. Müller, 2, Bolton Terrace, Newcastle-upon-Tyne (E) Feb. 1898

S.

Sanderson, Thomas H., 31, Park Road, Jarrow-on-Tyne ... ... (E) Feb. 1898
Saul, John W., 55, Manor House Road, Newcastle-upon-Tyne ... (E) Mar. 1898
Scott, Alex. C., Malvern House, Edward's Road, Whitley, Newcastle-upon-Tyne ... ... (E) Jan. 1895
Scott, Joseph, 49, Leazes Terrace, Newcastle-upon-Tyne ... ... (E) Dec. 1891
Scott, W. A., 100, George Road, Newcastle-upon-Tyne ... ... (E E) Oct. 1894
Shand, William Lamont, 39, Holly Avenue, Newcastle-upon-Tyne (E) Nov. 1895
Short, Thomas Smart, c/o Messrs. Short Brothers, Pallion, Sunderland... ... ... (S) Oct. 1892
Sitwell, John Knightley, 24, Archbold Terrace, Newcastle-upon-Tyne ... ... (E) Nov. 1896
Smith, F. Henry, Construction Department, Messrs. Elder, Dempster & Co., African House, Water Street, Liverpool (E & S) May 1898
Smith, John E., 15, Eslington Terrace, Newcastle-upon-Tyne ... (E) Nov. 1897
Squire, Charles E., Corporation Electricity Works, Blackpool ... (E E) Nov. 1893
Stephenson, Robert, c/o Messrs. Robt. Stephenson & Co., Limited, South Street, Newcastle-upon-Tyne ... ... (E) Mar. 1894
Stuart, John, 57, Heaton Park Road, Newcastle-upon-Tyne ... (E) Dec. 1895

T.

Thomas, John P., 6, Queen Anne Terrace, Gateshead-on-Tyne ... (E) Dec. 1897
Thomas, Robert Gates, 6, Queen Anne Terrace, Gateshead-on-Tyne (E) Nov. 1894
Thomas, William, 4, Eton Avenue, Hampstead, London, N.W. ... (E) Oct. 1895
Todd, George William, 26, Bede Burn Road, Jarrow-on-Tyne ... (S) Jan. 1898
Townend, Sidney, 3, St. Eleanor Street, Cullercoats ... ... (E) Nov. 1895
Turner, Charles N., 2, Newburn Lane, Newburn-on-Tyne... ... (E) April 1896

V.

Vardy, George, Neptune Engine Works, Walker-on-Tyne... ... (E) Oct. 1894
Varty, B. S., 16, Hawthorn Street, Newcastle-upon-Tyne ... ... (S) Oct. 1895
Vaughan, Wm. A., The Poplars, Gosforth, Newcastle-upon-Tyne... Jan. 1898

W.

Wadd, Herbert W. F., c/o Messrs. Bruce, Harman, & Co, 48, West Regent Street, Glasgow ... ... (E) Feb. 1898
Waddingham, W. H., 30, Renfrew Road, Wallsend-on-Tyne ... (E) Nov. 1897
Walker, Gavin Knox, 87, Jesmond Road, Newcastle-upon-Tyne ... (E) Mar. 1894
Ward, Ebenezer T., 22, Warrington Road, Newcastle-upon-Tyne (E) Mar. 1898
Ward, Joseph P., Public Works Department, Eshowe, Zululand ... (E) Oct. 1895
Watson, John, 108, Meldon Terrace, Heaton, Newcastle-upon-Tyne ... ... (S) Dec. 1897

		ELECTED.
White, Hedley, 6, Crown Gardens, Dovanhill, Glasgow	(S)	Nov. 1897
Wildridge, Richard, 9, Grasmere Terrace, Gateshead-on-Tyne ...	(E)	Oct. 1895
Wilkin, Ernest Vivian, 11, Appold Street, Finsbury, London, E.C.	(E)	Nov. 1892
Wilson, Edward, 13, Ely Street, Gateshead-on-Tyne	(E E)	Jan. 1898
Wilson, John R. S., Lyndhurst, Gosforth, Newcastle-upon-Tyne ...	(E)	Mar. 1894
Wilson, Percy P., Bank House, Fawcett Street, Sunderland ...	(S)	Jan. 1896
Wilson, William S., 123, Osborne Road, Newcastle-upon-Tyne ...	(E)	Nov. 1897
Wood, Lionel, 90, Rothbury Terrace, Heaton, Newcastle-upon-Tyne	(E E)	Nov. 1897
Wotherspoon, William L., 13, Bellerby Terrace, West Hartlepool	(E)	Jan. 1898
Wright, George Hudson, 35, Washington Terrace, North Shields...	(E E)	Feb. 1896

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETINGS HELD ON MAY 9TH, 1888, MAY 13TH, 1889, MAY 11TH, 1891, MAY 14TH, 1895, AND MAY 13TH, 1898.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders." Name.

II.—The OBJECTS for which the Institution is established are:—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions. Objects.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect. Honorary Members.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum. Members.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum. Associates.

aduates.

VII.—GRADUATES may be persons under twenty-four years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum.

fe Members d Associates.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of Twenty Guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of Ten Guineas. All such compositions shall be deemed to be capital moneys of the Institution.

ficers.

IX.—The COUNCIL of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, eighteen Vice-Presidents, fifteen Ordinary Members of Council, and an Honorary Treasurer.

tion of ers. Bye-Law 11.)

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Ordinary Members of Council shall be elected annually. The retiring Vice-Presidents shall be those who have been in office for the longest period, and Ordinary Members of Council those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents shall be eligible for re-election. The retiring Ordinary Members of Council shall not be eligible for re-election to the same office until after an interval of one year, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

onorary Members' Privileges.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions.

mbers' rileges.

XII.—Members shall have all the privileges of the Institution as enumerated in the foregoing paragraph, and shall be eligible for office.

ociates' rileges.

XIII.—Associates shall have all the privileges enumerated in raph XI. They shall be eligible for office as Ordinary Meml of Council.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolutions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office. Graduates' Privileges.

XV.—The General Meetings of the Institution shall be held during the months of October to May, inclusive, of each year. General Meetings.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the Form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday. Candidates for Admission.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix. Graduates becoming Members.

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be Balloting for Members.

returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and shall become due on the 1st of August each year. Any Member, Associate, or Graduate, wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of August following.

Receipt of Subscription.

7.—On payment of each subscription the Secretary shall forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be unknown in the meeting shall only be able to claim the privilege in question on proving his membership for the current Session.

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to Form E in the Appendix; and in the event of its continuing in arrear until the end of that Session after such application, the Council shall have the power, after remonstrance by letter, according to the Form F in the Appendix, of declaring that the defaulter has ceased to be a member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall,

in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

Election of Officers.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be one in excess of the number required in each section of the Council. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members of Council, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, eighteen Vice-Presidents, one Honorary Treasurer, and fifteen Ordinary Members of Council, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to

them as Ordinary Members of Council, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any such Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting.

12.—The result of the ballot for Officers shall be declared at the Closing Business Meeting, to be held in May, at which meeting general business shall be transacted. At this meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the persons whose places they fill would have retired. Vacancies not filled during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and the Closing Business Meeting in May; each of these meetings shall be held in Newcastle-upon-Tyne. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

Notice of Meetings.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution.

Special General Meetings.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition, signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the requisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special Meeting. Quorum.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents; or in the absence of these, an Ordinary Member of Council shall take the chair; or if no Member of Council be present and willing to take the chair, the meeting shall elect a Chairman. Chairman at Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote; otherwise he shall not vote. Decisions of General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened. Questions of a Personal Nature in General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed. Transactions of Business General Meetings.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be Dissolving a General Meeting.

dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

Adjourning a General Meeting.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

Introduction of Friends.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it.

COUNCIL MEETINGS.

Council Meetings.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known.

Convening Meeting for Expenditure of Funds.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business.

Discussions of Personal Character.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential.

Regulation of Proceedings.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number.

Chairman and Quorum.

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Ordinary Members of Council shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum.

Sub-Committees.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case,

and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution. **Sub-Committees.**

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best. The President shall, *ex-officio*, be a member of all Committees. **Sub-Committees.**

29.—Any member may by communication addressed to the Secretary petition the Council to lay before a General Meeting of the Institution the contents of any letter which shall in a short, concise, and clear manner draw the attention of the Institution to public matters of importance in connection with legislation proposed by any governing body in reference to the construction of ships, machinery, or the working of the same, so that members may by their scientific and practical knowledge demonstrate the soundness or otherwise of the proposed measure. **Communication to Council.**

30.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote. **Invitation to Strangers.**

31.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance **Secretary and Treasurer's Duties.**

Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution.

Finance Committee.

Payment of Accounts.

Reading and Library Committees.

32.—The following Sub-Committees shall be appointed annually at the first meeting of the Council in each Session:—(1) A Finance Committee, to consist of seven persons, viz.: one Past-President or Vice-President, who shall be Chairman; five Members of Council, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque, signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary and the Honorary Treasurer. (2) A Reading Committee, to consist of six members of Council. No member who has served on this Committee for three years in succession shall be eligible for re-election until after an interval of one year. (3) A Library Committee, in accordance with Library Rules, Nos. 1 and 3. (4) A Graduates' Award Committee to consist of five members.

TRANSACTIONS.

Papers to be submitted to Council.

Reading Sub-Committee.

Synopsis of Papers.

33.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through. The Reading Sub-Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered. A synopsis of the subject-matter of each paper shall be forwarded to the Secretary, by the writer, for insertion in the circular convening the meeting at which the paper is to be read.

Printing Transactions.

34.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for

distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

Copy of Papers supplied to members before reading, etc.

35.—Copies of papers to be read during any Session will be sent seven days before the date of reading to members who shall have applied to the Secretary for them, in writing, at the commencement of the Session. The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting, prior to the reading of the paper set down for that date.

Proofs sent to members for Correction.

36.—The Secretary shall send to each speaker as soon as possible after a General Meeting a copy in manuscript of the speaker's own remarks for correction. This copy must be returned to the Secretary within four days. A printed proof will also be sent to each speaker for further revision; this must be returned to the Secretary within three days, otherwise it will be deemed correct, and printed off after receiving verbal corrections.

Liberty to Print Explanatory Notes.

37.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications must be approved by the Reading Committee, and shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

38.—The Institution shall not be held responsible for the statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

39.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 42.

Transactions not supplied to members in Arrears.

40.—The Transactions shall not be supplied free to members whose subscriptions are unpaid.

Members not to receive Transactions till after First Payment.

41.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the Session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

42.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. Additional copies of papers required by authors for their private use can only be procured from the Secretary, at prices fixed by the Council from time to time, and these copies must contain the whole of the discussion following the papers, and be bound in the usual cover, with the addition of the following words:—"By permission of the Council," and "Excerpt Minutes of Proceedings." Duplicate volumes and copies of parts of the Transactions, if in print, can also be obtained from the Secretary, and shall be sold only by him, in such manner and at such prices as the Council shall have fixed.

Rule of Discussion.

43.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes.

ACCOUNTS, &c.

Accounts.

44.—The Council shall present the yearly accounts (up to the 31st of July preceding) at the Annual General Meeting in October of each year, after they have been audited by a professional Accountant, appointed by the members at the Closing Business Meeting in May.

Trustees.

45.—The capital, stock, and funds of the Institution shall be vested in the names of three Trustees, to be elected from time to time as vacancies occur by the members of the Institution at a General Meeting called for that purpose. All mortgages and other securities shall be taken in the names of such Trustees; and on any new appointment the funds shall vest in the newly-appointed Trustee or Trustees jointly with the continuing or remaining Trustee or Trustees.

Investment of Funds.

46.—The Finance Committee may, with the consent of the Council, invest in the names of the appointed Trustees of the Institution any moneys not immediately required for the purposes of the Institution, in or upon any approved securities.

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

47.—Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the

Closing Business Meeting in May, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the Closing Business Meeting in May in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the Closing Business Meeting in May.

Vote by Proxy.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19.

THE GOLD MEDALS.

RULES.

1.—That papers read by members of the Council shall be eligible for the Gold Medals' Award.

2.—That the medals shall be awarded by the vote of the Council given at a meeting of the Council at which the business has been specially noted on the circular convening the meeting, and not by ballot papers previously sent out, as has hitherto been the custom.

3.—That when the Council proceeds to award the medals, authors of papers who are members of the Council shall not be present nor vote at such Council meetings.

4.—If at the meeting convened a quorum of the Council should not be present, or if the Council considers it desirable or cannot agree, the decision of the Council may be deferred and adjourned to a future meeting.

5.—That the medals shall be awarded annually, provided the papers are, in the opinion of the Council, worthy of the award, but not otherwise; and that they be awarded to the authors of the best papers, irrespective of their having previously obtained a gold medal.

APPENDIX TO BYE-LAWS.

FORM A. (BYE-LAW 1.)

Name (in full)
Profession or Occupation and where Employed
Address
being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned, propose and recommend that he shall become*
thereof. We know him to be†
and eligible for the proposed membership.

* A Member, Associate, or Graduate.

† A Principal, Manager, or Draughtsman, etc. See Articles V., VI., and VII. of Constitution.

	FROM PERSONAL KNOWLEDGE.	SECTION OF MEMBERSHIP
Proposed by		
Supported by Three Members or Associates.		

Dated this day of

(*When a Graduate is proposed the age last birthday should be stated.*)

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a Graduate of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-four years of age, and being desirous of becoming a Member of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(*Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.*)

Signed _____ _____ } Three [Members or Associates.]
_____
_____

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

Member, Associate, or Graduate.	Occupation.	Address.	Nominated by.	Supported by Three Members or Associates.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

Sir,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr._____ ____

Address_____ ____

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of* £ : : "

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £ of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be).

I am, Sir,

Yours faithfully,

Secretary.

FORM H. (BYE-LAW 11.)

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

——— President for the current year (eligible for re-election.)*

——— ———
——— ——— } New Nominations, from whom to select ONE.
——— ———

VICE-PRESIDENTS.—EIGHTEEN NAMES only to be returned (including the fifteen who remain in office), or the vote will be lost.

——— ———
——— ———
——— ———
——— ———
——— ———
——— ——— } Fifteen Vice-Presidents remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.

——— ———
——— ——— } Three Vice-Presidents retiring, eligible for re-election.
——— ———

——— ———
——— ———
——— ———
——— ———
——— ——— } New Nominations, from whom to select THREE.

TREASURER.—ONE NAME only to be returned, or the vote will be lost.

——— Treasurer for the current year, eligible for re-election.

——— ———
——— ——— } New Nominations, from whom to select ONE.
——— ———

ORDINARY MEMBERS OF COUNCIL.—FIFTEEN NAMES only to be returned, including the ten who remain in office.

——— ———
——— ———
——— ———
——— ———
——— ———
——— ———
——— ———
——— ———
——— ———
——— ——— } Ten Ordinary Members of Council remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.

——— ———
——— ———
——— ———
——— ———
——— ——— } Five Ordinary Members of Council retiring, and NOT eligible for re-election.

——— ———
——— ———
——— ———
——— ———
——— ———
——— ———
——— ——— } New Nominations, from whom to select FIVE.

* To be crossed out before issue, when the President is not eligible for re-election.

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Ordinary Members of Council, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM J. (BYE-LAW 45.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY.

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,....., being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr..... who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the... .....day of ....., 18....., and at any adjournment thereof.

Signature.....

Address.....

.....

.....*Secretary.*

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Supplementary Bye-Laws Relating to the Graduate Section.

I.—The Graduate Section shall be controlled by the General Bye-Laws of the Institution, and the following Bye-Laws are supplementary to these.

This Section shall be open to all Members of the Institution who are under twenty-six years of age, who shall be at liberty to express their views upon any subject brought before the General Meetings of the Section.

Officers by Ballot.

II.—The Officers of the Section shall be elected from and by the Graduates, in accordance with the Form given in the Appendix, and shall consist of one Chairman, one Honorary Secretary, and five Committee-men. The Committee shall have power to select one of its members to act as Assistant Honorary Secretary if required.

Election of Officers.

III.—(*a*) The Officers shall be elected annually, and shall all be eligible for re-election until the age limit is reached.

Rider to General Bye-Law No. 11.

(*b*) Any voting paper returning either more or less than one Chairman, one Honorary Secretary, and five Committee-men shall be disqualified.

General Meetings.

IV.—The Annual General Meeting shall take place as early as possible after that of the Institution in the month of October, and the Closing Meeting shall be held prior to the Closing Business Meeting of the Institution in May.

Special General Meetings.

V.—A Special General Meeting may be convened at any time by the Committee. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

Quorum.

VI.—Nine Members shall constitute a quorum for the purpose of a General Meeting.

Excursions.

VII —Excursions shall be arranged during the Session as the Committee may find expedient. Any Graduate wishing to intro-

duce a friend at such excursions must submit the name of his friend to the Committee at least three clear days before the date of the excursion.

Seven clear days' notice of every excursion shall be given to every Member of the Graduate Section.

COMMITTEE MEETINGS.

Committee Meetings.

VIII.—The Committee shall meet at as early a date as possible after the holding of a General Meeting, and on other occasions when the Chairman shall deem it necessary, being summoned in either case by circular, stating the time of meeting and the business so far as is known. All discussions of a personal character in the Committee shall be considered and treated as being strictly confidential.

Four members of Committee, including the Chairman, shall form a quorum.

Duties of Hon. Secretary.

IX.—The Honorary Secretary shall act under the direction and control of the Committee. He shall attend all Meetings, Committee and General, and shall take minutes of the proceedings and enter them in proper books provided for the purpose. He shall write the correspondence of the Graduate Section and Committee (excepting that arranging for excursions, which shall be arranged by the Secretary of the Institution). He shall keep a stamp account book, which on all occasions shall be open to the inspection of the Secretary of the Institution.

PAPERS.

Synopsis of Papers to be read.

X.—The author of a paper shall forward to the Honorary Secretary, at least fourteen days before the date of the reading of the paper, its title and a synopsis of the contents; a copy of the synopsis to be forwarded to every Graduate, together with the notice convening the meeting at which the paper is to be read.

Copies of Papers to be forwarded to the Secretary of the Institution.

XI.—After the reading of a paper a copy must be forwarded to the Secretary of the Institution in time to be placed before the Graduate Awards Committee. This copy, if deemed necessary by the Council, shall become the property of the Institution, and be placed upon the shelves in the Library. These copies, together with any sketches accompanying them, shall be written upon paper of uniform size.

APPENDIX.

GRADUATES' BALLOTING LIST.

CHAIRMAN.

*——— (E)
——— ( ) } Nominations from whom to select ONE.

HON. SECRETARY.

*——— (E)
——— ( ) } Nominations from whom to select ONE.

COMMITTEE.

*——— (S)
*——— (EE)
*——— ( )
——— ( )
——— ( )
——— ( ) } Nominations from whom to select FIVE.

NOTES.

1.—Any list having either more or less than the required number of names will be disqualified.

2.—All voting papers must be returned to the Secretary of the Institution on or before the day of , 18 .

3.—No signature must be put on this paper.

4.—* Signifies a member of the old committee.

5.—(E) Denotes Engineer; (EE) Electrical Engineer; (S) Shipbuilder.

6.—A copy of this list shall be posted, at least fourteen days previous to the Closing Meeting of the Session, to every Graduate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

7.—Votes as Chairman or Hon. Secretary, for persons not so elected, will count for them as members of committee.

THE LIBRARY AND READING ROOM RULES.

Committee.

1.—The Library and Reading Room shall be managed by a Committee, called the Library Committee, who shall have charge of all books, papers, specimens, etc., which may belong to the Institution. It shall consist of five members of the Institution, of whom at least two shall be members of Council.

Property.

2.—The books and other property of the Library shall be vested in the Trustees appointed by the Institution.

Appointment of Committee.

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each Session. No member who has served on the Committee for three years in succession shall be eligible for re-election until after an interval of one year. The Chairman shall be elected by the Council.

Librarian.

4.—The Secretary of the Institution shall be Librarian, and shall also act as Secretary to the Library Committee. Three members of the Committee shall form a quorum.

Duties of Committee.

5.—The Library Committee shall be responsible for the binding and purchasing of books, periodicals, papers, etc., and for the expending of all money voted by the Council for its use. It shall appoint an attendant who shall act as Assistant Librarian. It shall make Rules for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of the Council held after the annual scrutiny of the books referred to in Rule No. 13.

Hours of Opening and Closing, etc.

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library and Reading Room shall be open for consulting, borrowing, or returning books, every week day as follows:—

On Monday, Tuesday, Wednesday, and Friday	10 a.m. to 12 noon. 1 p.m. to 5·30 p.m. 7 p.m. to 9 p.m.
On Thursday	10 a.m. to 12 noon. 1 p.m. to 5·30 p.m.
On Saturday	10 a.m. to 1 p.m. 3 p.m. to 9 p.m.

The Rooms will be closed on Christmas Day and the day following, New Year's Day and the day following, Good Friday and the day following, Monday and Tuesday in Easter week and

Whit week, on Tuesday, Wednesday, Thursday, Friday and Saturday in the Race week of June, and the first Monday in August (being Bank Holiday); also from the second to the fourth Saturday in July of each year, as mentioned in Rule No. 13.

Lending of Books.

7.—Books shall not be lent to any persons except Members, Associates, or Graduates of the Institution, but a person entitled to borrow a book may send a messenger with a signed order for it.

Visitors.

8.—Each member shall be entitled to introduce a friend to the Reading Room, whose name shall be written in the Visitors' Book, together with that of the member introducing him.

Reference Books.

9.—The books marked with an asterisk in the Catalogue shall be kept only for consultation in the Library, and shall not be lent. Pending the preparation of a Catalogue, the Librarian shall be instructed by the Committee as to which books shall be withheld from circulation.

Unbound Books.

No periodicals, magazines, or pamphlets shall be issued for circulation until after they have been bound and added to the Lending Library.

Register of Books Lent, etc.

10.—The Librarian shall keep a register in which he himself or the attendant shall enter the titles of the books lent, the date of lending, the name of the borrower, and the date of the return of the book to the Library. The borrower of the book or the bearer of his order shall initial the entry of such borrowing, and the Librarian or the attendant shall initial the date of the return of the book.

Number Lent to each member.

11.—No person shall borrow or have in his possession at one time more than two volumes belonging to the Library.

Return of Books.

12.—No member shall retain a book longer than fourteen days, excluding the day of issue. He shall be responsible for the safe return of the book, and if it be damaged or lost he shall make good the cost of such damage or loss.

Yearly Inspection of Books.

13.—All books belonging to the Library shall be called in for inspection, and the lending out of books shall be suspended from the second to the fourth Saturday of July, inclusive, of each year, and members shall be required by notice to return all books in their hands before the period mentioned.

Fine.

Members failing to comply with this injunction shall pay a fine of two shillings and sixpence.

14.—Members are requested, when in the Reading Room or Library, to contribute to the general comfort by carefully abstaining from loud talking and noise of any kind. Smoking is not permitted in the Library.

Members in Arrears.

15.—Any member being twelve months in arrears with his subscriptions to the Institution shall not be at liberty to use the Library or Reading Room after the commencement of the first Session following.

N.B.—The foregoing Rules may be amended at any time by the Library Committee with the sanction of the Council.

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897–98.

PROCEEDINGS.

The Fourteenth Session of the Institution was opened on the evening of the 14th day of October, 1897, with a conversazione and ball, at the invitation of the President (Col. Henry F. Swan, J.P.), in the Assembly Rooms, Westgate Road, Newcastle-upon-Tyne, and was attended by a large assemblage of ladies and gentlemen.

FIRST BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON FRIDAY EVENING, 5TH NOVEMBER 1897.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Closing Business Meeting of last session, held in Newcastle-upon-Tyne, on May 12th, 1897, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. Robert Thompson and J. R. Fothergill to examine the voting papers, and the following gentlemen were declared elected : —

MEMBERS.

Brash, James, E.E. Draughtsman, 2, Bolton Terrace, Newcastle-upon-Tyne.
Christie, Reginald, Electrical Engineer, Woodside, Tynemouth.
Coates, Matthew C., E. Draughtsman, 26, Denmark Street, Gateshead-upon-Tyne.
Dawson, Herbert, E.E. Draughtsman, 176, Prince Consort Road, Gateshead-upon-Tyne.
Deighton, William, Director, Messrs. Deighton's Patent Flue Co., Vulcan Works, Pepper Road, Leeds.
Eidman, William, Supt. Engineer, 89, Plymouth Road, Penarth.
Graham, James Thos., Engineer, 126, Westmoreland Road, Newcastle-upon-Tyne.
Griffith, Edwin, Engineer, Pier Cliff House, Tynemouth.
Haramtishi, M., Student in Naval Architecture, 13, Eversley Place, Heaton, Newcastle-upon-Tyne.
Jack, Charles Kellie, Ship Draughtsman, 35, Cranbourne Terrace, Stockton-on-Tees.
Jewitt, Charles Wm., Dry Dock Manager, West Park View, Stanhope Road, South Shields.
Kaneda, Wasaburo, Ship Inspector, 39, Grove Street, Newcastle-upon-Tyne.
Lang, William Veysey, Engineer, Messrs. Allsop & Co., Shipbuilders and Engineers, Preston, Lancashire.
Mail, M., Jun., Engineer, 8, Ashbrook Terrace, Sunderland.
Montgomerie, Hugh, Ship Draughtsman, 38, King John Terrace, Heaton, Newcastle-upon-Tyne.
Moore, Wm. Henry, Engineer, 18, George Road, Wallsend-on-Tyne.
Nicholson, Thos. Head, Supt. Engineer, 90, Rye Hill, Newcastle-upon-Tyne.
Ormonde, John Grey, Engineer, 35, Percy Gardens, Tynemouth.
Perrett, Jos. Richard, Naval Architect, Victoria Villa, Low Fell, Gateshead-upon-Tyne.
Pirrie, Norman, E. Draughtsman, Brook House, 10, Wallbrook, London, E.C.
Rosen, Jacob, Ship Draughtsman, Messrs. Armstrong, Whitworth, & Co., Elswick Shipyard, Newcastle-upon-Tyne.
Wedgwood, Josiah, Naval Architect, Messrs. Armstrong, Whitworth, & Co., Elswick Shipyard, Newcastle-upon-Tyne.
Willcox, Henry Walker, Consulting Engineer, 68, John Street, Sunderland.
Willcox, Percy F. C., Consulting Engineer, 68, John Street, Sunderland.
Wood, William, Shipbuilder, 6, Eslington Terrace, Newcastle-upon-Tyne.

GRADUATES TO MEMBERS.

Adams, Cecil T., Marine Engineer, 196, Holland Road, Kensington, London, W.
Brown, Geo. Matthew, Engineer, Birk Heads, Marley Hill, Swalwell, R.S.O.
Cookson, John A., E. Draughtsman, 2, St. Edmund's Road, Gateshead-upon-Tyne.
Edminson, Frank A., Ship Draughtsman, Fairfield House, Dumbarton Road, Partick, Glasgow.
Hughes, Thos. Charles, Engineer, 3, Summerhill Street, Newcastle-upon-Tyne.
Lace, Basil T., E. Draughtsman, 26, Heaton Grove, Heaton, Newcastle-upon-Tyne.
Robson, Nathaniel E., E. Draughtsman, 11, Point Pleasant Terrace, Wallsend-on-Tyne.
Stephens, H. C. J., Engineer, 94, Fortess Road, London, N.W.

ASSOCIATES.

Bell, Alfred, Shipowner, 11, Osborne Terrace, Newcastle-upon-Tyne.
Coates, Henry, Marine Surveyor, Hamburg Chambers, Newcastle-upon-Tyne.
Harrison, Samuel Turner, Accountant, The Green, Wallsend-on-Tyne.
Raine, John, Shipowner, Baltic Chambers, Sunderland.
Sutherland, Arthur M., Shipowner, 7, Collingwood Terrace, Newcastle-upon-Tyne.
Winstanley, Robt. Hope, Accountant, 8, Kenilworth Road, Newcastle-upon-Tyne.

GRADUATES.

Adams, Jas. Wilson, E.E. Apprentice, 8, Belle Vue Terrace, Gateshead-upon-Tyne.
Adamson, Charles P., E. Draughtsman, 29, North View, Heaton, Newcastle-upon-Tyne.
Bolam, J. H., E. Student, 46, Northumberland Street, Newcastle-upon-Tyne.
Currie, Hugh B., E. Apprentice, 41, Eldon Street, Newcastle-upon-Tyne.
Dixon, John Wm., E. Apprentice, 7, Belle Vue Terrace, Gateshead-upon-Tyne.
Donaldson, Henry B., S. Apprentice, 10, Lily Crescent, Jesmond West, Newcastle-upon-Tyne.
Hamilton, James, E. Draughtsman, Messrs. The Royal Shipbuilding and Engineering Co., Flushing, Holland.
Hobbs, Arthur, E. Draughtsman, 9, Grasmere Terrace, Gateshead-upon-Tyne.
Hutton, John S., E. Apprentice, 17, Claremont Place, Newcastle-upon-Tyne.
Moore, Jas. Forster, Electrical Engineer, 6, Princess Street, Sunderland.
Murray, Athole J., S. Apprentice, Hassendean, Beech Grove, Newcastle-upon-Tyne.
Robinson, Francis, Engineer, Willington Rectory, Newcastle-upon-Tyne.
Smith, John E., E. Apprentice, 15, Eslington Terrace, Newcastle-upon-Tyne.
Waddingham, W. H., E. Apprentice, 30, Renfrew Road, Wallsend-on-Tyne.
White, Hedley, Ship Draughtsman, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne.
Wilson, William S., E. Student, 123, Osborne Road, Newcastle-upon-Tyne.
Wood, Lionel, E.E. Apprentice, 90, Rothbury Terrace, Heaton, Newcastle-upon-Tyne.

The SECRETARY (Mr. Duckitt) submitted the Council's Thirteenth Annual Report and Financial Statement.

The PRESIDENT delivered a short Address.

Mr. ARCHIBALD HOGG read a paper on "The Comparison and Construction of Ships' Lines."

COUNCIL REPORT.

THIRTEENTH SESSION, 1896–97.

The Council has pleasure in stating that the finances of the Institution are still in a satisfactory condition. The income from the last year ending July 31st was £[illegible] 19s. 5d. Of this the Council has invested the sum of £300 on mortgage with the Tyne Improvement Commissioners for 15 years at an interest of 4 per centum per annum.

The Committee appointed to consider the rules relating to the awarding of the gold medals having submitted for the acceptance of the Council certain alterations, these alterations were referred to the donors, and have received their approval and sanction. The new rules are now attached to the bye-laws of the Institution.

The thirteenth session was opened with an inaugural address given by the new President, Col. Henry F. Swan, J.P.; and during the session the following papers were read and discussed:—

"Water-gauges for High-pressure Steam Boilers." By Mr. T. C. Billcup.
"The Experimental Engines at the Durham Colliery of Science, Newcastle-upon-Tyne, with some Results from same." By Prof. E. L. Weighton, M.A.
"The Resistance Areas of Transverse Sections." By Mr. A. E. Sharp.
"Liquid Fuel." By Mr. R. Wallis, Wh. Sc.
"The Machine-cutting of Accurate Bevel and Worm Gears." By Mr. J. H. Gibson.
"High Pressures for Marine Engines." By Mr. W. R. Cummins.
"Gravitation Stamp Mills for Quartz Crushing." By Mr. D. B. Morison.
The discussions on Mr. J. F. Walliker's paper on "Notes on the Maintenance and Repairs of Marine Boilers" and Mr. J. R. Fothergill's paper on "Marine Boilers, particularly in reference to Efficiency of Combustion and Higher Steam Pressures," both of which papers were read at the Institution's meeting in Cardiff, were continued and closed.

With the view of extending the influence of the Institution, the Council arranged to hold a general meeting of the members at South Shields. The experiment proved a success, and it is intended to hold a similar meeting during the ensuing session.

The engineering gold medal for the twelfth session was presented to Mr. J. Denholm Young for his paper on "The Application of the Law of Similarity to Marine Propellers."

By the express desire of certain members of the Institution, the Council resolved to hold an Institution dinner in Newcastle-upon-Tyne

last February. This was so well supported by the members and their friends that it has been suggested to make it an annual function of the Institution.

During the eighth session of the Graduate section the following papers were read and discussed, and the Council has pleasure in reporting that the meetings were well attended :—

Opening Address by the Chairman (Mr C. W. Cairns).
"Notes on Water Tube Boilers, as applied to Marine Work," By Mr. B. G. Nichol.
"Notes on Screw Propellers." By Mr. R. Hinchliffe.
"Refrigeration on board Ships." By Mr. F. A. Edminson.
"An Analysis of some Types of Throttling Governors." By Mr. W. Lumley.
"Weights on Locomotive Wheels." By Mr. J. Bowden.
"Evaporation as carried out at the present time on board vessels of the Mercantile Marine, for purposes of Auxiliary Feed." By Mr. R. J. N. Willcox.

The following places of interest were also visited, and the thanks of the Institution are due to the principals and managers of the various works for the kind and hospitable manner in which the Graduate members were received and the care taken to render their visits instructive :—

Messrs. Corbitt & Sons', Rope Works, Hebburn-on-Tyne.
The Hartley Pit of the Seaton Coal Company.
Sir James Laing's Shipyard, Deptford, Sunderland.
The Northumberland Engine Works of the N.E. Marine Engineering Company, Wallsend-on-Tyne.

Thanks are also due to Mr. F. Caws, of Sunderland, for his kindness in placing his rooms at the disposal of the Graduates in which to hold their Sunderland meeting.

The prizes for the best papers read in this section during the previous (seventh) session were awarded as follows, the prizes being equal in value :—

To Mr. J. B. Bent, for his paper on "Alternating Current Motors on Single Phase Mains."
To Mr. R. G. Thomas, for his paper on "Some Notes on the Methods of Generating and Distributing Electric Power."

Mr. C. W. Cairns has been re-elected Chairman for the ninth session, and Mr. B. G. Nichol has been elected Honorary Secretary.

During the year the following additions have been made to the list of members :—Life Member, 1 ; Members, 49 ; Associates, 5 ; Graduates, 13 ; and 7 Graduates have been raised to the rank of Members.

The Council regrets to have to record the loss by death of the following :—Life Members, Mr. Hugh Macoll, V.P., and Mr. David

Halley; Members, Messrs. W. Archbold, A. Blechynden, D. Cameron, Hedley Chapman, A. C. Coning, E. M. Dadd, J. T. Eltringham, H. Feldtman, Edwin Graham, T. F. Irwin, and W. Putnam; Associate, Mr. T. Metcalfe; Graduates, Mr. T. Carter and Mr. Bede Hancock.

The Institution has also lost by resignations and other causes 43 Members, 5 Associates, and 14 Graduates.

In consequence of a large percentage of the Members neglecting to pay their subscriptions in conformity with the requirements of Bye-law 6, the Council considered it necessary to recommend an alteration in Bye-law 40, prohibiting the issue of copies of the *Transactions* to members whose subscriptions are unpaid. This was agreed to by the general body of members at the Closing Business Meeting of the session.

Mr. John Gravell's term of office as representative of this Institution on the Council of the Durham College of Science having expired, he was re-elected by the Council as the Institution's representative for a further period of four years.

Mr. Summers Hunter and Mr. G. E. Macarthy have also been re-elected to represent the Institution on the Sub-Committees of the Northumberland County Council Technical Education Committee.

NORTH-EAST COAST INSTITUTION OF

STATEMENT OF RECEIPTS AND PAYMENTS

Receipts.

		£ s. d.	£ s. d.
To Balance from last Account—			
At Bank			378 19 5
„ Subscriptions received for Session 1896-97—			
246 Members at £2 2s.	£516 12 0		
471 Members „ £1 1s.	494 11 0		
121 Associates „ £1 1s.	127 1 0		
119 Graduates „ 10s. 6d.	62 9 6		
957		1,200 13 6	
„ Association of Foremen Engineers and Draughtsmen—			
One year's Subscription		20 0 0	
„ Life Member—H. B. Rowell		21 0 0	
„ Subscriptions received in advance—			
1 Member for Session 1897-8	£2 2 0		
1 Member „ 1898-9	2 2 0		
1 Associate „ 1897-8	1 1 0		
2 Graduates „ 1897-8	1 1 0		
		6 6 0	
„ Arrears for Sessions 1893 to 1896—			
13 Members at £2 2s.	£27 6 0		
24 Members „ £1 1s.	25 4 0		
6 Associates „ £1 1s.	6 6 0		
8 Graduate „ 10s. 6d...	4 4 0		
		63 0 0	
			1,310 19 6
„ Transactions sold this Session		40 15 0	
„ Copies of Members' Papers supplied		37 19 3	
			78 14 3
„ Tyne Improvement Commissioners—			
One Year's Interest to 21st June, 1897, on £605, at 3½ per cent.		21 18 6	
Viz.:—Medal Fund	£274 0 0		
Graduates' Award and Life Members' Fund	331 0 0		
	£605 0 0		
Less—Tax		0 14 5	
			21 4 1
One Year's Interest to 10th July, 1897, on £500, at 3¾ per cent.		18 15 0	
Less—Tax		0 12 6	
			18 2 6
Half-year's Interest to 4th May, 1897, on £300, at 3 per cent.		4 10 0	
Less—Tax		0 3 0	
			4 7 0
			£1,812 6 9

ENGINEERS AND SHIPBUILDERS.

FOR SESSION ENDING 31ST JULY, 1897.

Payments.

	£	s.	d.	£	s.	d.
By Transactions and Papers—						
Lithographing	149	7	9			
Printing and Binding	314	10	0			
				463	17	9
„ Stationery and Circulars	69	14	6			
„ Reporting	23	16	0			
„ Rents—						
Offices	111	4	0			
Lecture Room	8	9	0			
Telephone	8	0	0			
„ Rates, Gas, Electric Light, and Insurance...	30	5	5			
„ Salaries—						
Secretary, Salary	275	0	0			
„ Commission	64	11	0			
Assistant Librarian	35	0	0			
Office Boy	10	0	0			
„ Postages, Stamps, Post Cards, Parcels, etc.	100	0	8			
„ Secretary's Expenses and Allowances to Hall Keepers, etc.	28	2	8			
„ Office Expenses, Coals, Cleaning, etc.	23	6	0			
„ Measured Mile Posts—Rent...	6	6	0			
„ Auditor's Fee	5	5	0			
„ Lantern Expenses	2	3	6			
				801	3	9
„ Library Account—						
New Books	7	9	9			
Bookbinding	13	10	3			
				21	0	0
„ New Furniture				4	14	0
„ Gold Medals' Fund—						
One Gold Medal awarded				5	10	0
„ Graduates' Award Fund—						
Amounts awarded for Papers				7	11	0
„ Tyne Improvement Commissioners—						
Amount invested at 3 per cent. for 15 years, from 4th November, 1896				300	0	0
„ Balance at Bank				208	10	3
				£1,812	6	9

THE BALANCE SHEET FOR SESSION ENDING 31ST JULY, 1897.

Liabilities.

		£ s. d.	£ s. d.
Gold Medals' Fund—			
Amount at 31st July, 1896 ...	£289 17 9		
Interest on Investment ...	9 12 1		
		299 9 10	
Less—One Medal awarded		5 10 0	
			293 19 10
Graduates' Award Fund—			
Amount at 31st July, 1896 ...	£223 5 8		
Interest on Investment ...	7 11 3		
		230 16 11	
Less—Awards for Papers		7 11 0	
			223 5 11
Payments by Life Members and Associates—			
Amount at 31st July, 1896		147 0 0	
Add—Life Member this Session ...		21 0 0	
			168 0 0
Subscriptions paid in advance			6 6 0
General Capital			1,560 19 4
			£2,252 11 1

Audited and certified,
R. W. SISSON, F.C.A.

Newcastle-upon-Tyne,
25th October, 1897.

Assets.

		£ s. d.	£ s. d.
Subscriptions in Arrear—			
Session 1895–96		4 4 0	
„ 1896–97		44 2 0	
			48 6 0
Stock of Transactions, valued at			193 7 3
Office and Library Furniture, Safe, etc., as at 31st July, 1896	£150 5 4		
Less—Depreciation ...	15 0 0		
		135 5 4	
Additions this Session		4 14 0	
			139 19 4
Books in Library—			
As at 31st July, 1896 ...	£229 8 3		
Less—Depreciation ...	23 0 0		
		206 8 3	
Additions this Session—			
Purchases ... £7 9 9			
Bookbinding ... 13 10 3			
	21 0 0		
Books received in exchange ...	30 0 0		
		51 0 0	
			257 8 3
Tyne Improvement Commissioners—Investment in respect of the following Accounts, viz.:—			
Gold Medals' Fund		274 0 0	
Graduates' Award Fund		215 15 0	
Payments by Life Members and Associates		115 5 0	
General Capital		800 0 0	
			1,405 0 0
Cash—At Bank			208 10 3
			£2,252 11 1

The PRESIDENT had pleasure in moving the adoption of the Council's Report and Financial Statement.

Mr. G. D. WEIR seconded.

The reports were adopted *nem. con.*

OPENING REMARKS BY THE PRESIDENT.

The PRESIDENT said. I think you will consider the report of the Council to be very satisfactory, especially the financial side. The Institution has now got invested funds altogether of £1,405—£490 belongs to the Medal and Graduate Section—leaving a balance belonging to the Institution proper of £915. We commenced the year with a balance of £79, and this statement shows at the close of the financial year a balance of £208, so that during the year we have gained £129. As regards the number of members, we had last year a net balance of 974, that is, after deducting resignations and deaths, and we have now an accession by those who have been voted for to-night—25 Members, 6 Associates, and 17 Graduates, or 48 in all—so that the total membership is 1,022. I am sure you will all share with me the expression of regret at the serious list of losses we have suffered this year by death, amounting to 16, who were with us when we commenced the session, and who are not with us now. Amongst those I cannot help specially referring to Mr. Hugh Macoll, Vice-President, who, I was going to say, more than any other member almost of the Institution, but, certainly, second to none, laboured to promote and benefit the Institution in every possible way. He had its welfare thoroughly at heart, and spared no pains to promote its efficiency. We most deeply deplore his loss. We have also to regret the death of Mr. Blechynden, who was one of the earliest members of the Institution, and contributed very valuable papers from time to time. He has been cut off in his prime, and we all deplore his loss. I have referred to our having now 1,022 members of all classes, which is a large number, and I only wish that we could, in some way, infuse a little enthusiasm into a considerable proportion of that number so that our general meetings might be better attended than they are. I must say nothing during my term of office has been so disappointing to me as the small attendances. We seem to want something to stir us up and get a little fire into our discussions, and so promote interest and elicit conflicting opinions, if you like, so as to draw out points that might otherwise lie dormant. I may say the Graduates set us a good example in that respect. Some of the papers which have been read by them have been extremely interesting and instructive, and their discussions have been conducted with a good deal of enthusiasm, and I

am quite sure great good arises from these discussions, both to the students themselves at the present time, and I hope it will tend to make them very useful members of the Institution in the future. The experimental engine, which was kindly contributed by no less than 29 firms in the neighbourhood, has been of immense value to the Institution, and under the able care of Prof. Weighton will, I am sure, still further gives us most valuable information in the future. I have remarked upon the poor attendance, and I must say I was extremely sorry that Prof. Weighton had to read his most comprehensive and valuable paper on the results he had got from that engine to a very small audience. It is rather a poor return to a man who has given so much care, thought, and time, and prepared for them such an amount of valuable information, to find the members not there to receive it and countenance him in his efforts. I am sure Prof. Weighton will, in the future, be prepared to give us still further information on the results of his experiments, and I hope the members of the Institution will evince their interest in the matter by attending in larger numbers to hear him. It is always difficult, in getting papers, to have them of a sufficiently interesting character. It so happens that last year practically the whole of the papers were on engineering subjects. This session we are going to be rather the reverse, and practically the whole of the papers will be on shipbuilding subjects. We will now see whether our shipbuilding colleagues will take more interest in the matter than the engineering section did last session. One of the bye-laws (No. 24) provides that members may bring forward subjects that may be of interest in connection with Lloyd's sections, scantlings, and so on. If, therefore, anyone has suggestions to make in that respect the Institution will be very glad to hear them and have them put forward in the proper quarter. The paper to-night is a shipbuilding paper, and I hope you will find it an interesting and useful one. I will not detain you longer by any remarks of my own. I would only say this much with regard to what is of paramount interest at the present moment, that is the unfortunate strike now going on ; it is a subject that deeply affects us all, and I am quite sure that if the men and their leaders could be got to appreciate what foreign competition means the strike would, perhaps, never have occurred, or, at any rate, have been ended long ago. I feel justified in making these remarks in connection with a scientific institution, because I believe it is largely through the spread of technical knowledge in Germany and other countries that we are now having to face a competition which was never thought of in former years, and it is much more

deep and searching than the workmen care to believe; but we have only to cast around and see the splendid productions our foreign friends are making—for instance, the largest Atlantic "greyhound" has been built in Germany—in order to appreciate the fact that foreign competition is no bogey. Let us, as a scientific institution, try to do what we can to foster amongst our own people at home ideas as to how to produce ships and machinery in the cheapest way, coupled with the fullest efficiency, and thus be able to tackle foreign competition as far as in us lies.

THE COMPARISON AND CONSTRUCTION OF SHIPS' LINES.

By ARCHIBALD HOGG.

Read before the Institution, in Newcastle-upon-Tyne, on November 5th, 1897.

The writer's object in bringing forward this paper is to illustrate a method of comparison and construction of the under-water part of a ship's hull, a method which has been developed from a close study of the forms of ships of every description, more particularly those of the mercantile marine.

When designing a steamer, the naval architect arrives at the suitable proportions and power from the performance of previous ships; it is necessary, therefore, that he should be well acquainted with the ever varying form. If the value of a ship's form could be denoted by a single figure, the difficulty in comparisons and power estimates would be greatly simplified. The writer has not been able yet to accomplish this, but he hopes to explain how the form of any ship may be graphically ascertained from the position of a single spot on a diagram prepared with a series of curves.

In constructing the line plan the case is rather different, as we are now dealing with something more tangible. The writer will have pleasure in illustrating a method by which the architect is enabled to design the lines enclosing at one drawing the desired displacement and longitudinal position of centre of buoyancy, without trial and error, as is usual at present.

The writer is aware that much has already been written on this subject, but he believes there is still scope left for another paper.

Comparison.

For the purpose of studying and comparing the proportions of the hull, it is sufficiently accurate to use a block figure bounded by straight lines, but the block should be a very close approximation to the actual vessel. The block, which is proposed for this, is a modification of Dr. Kirk's block, as seen in Diagram C (Plate II.). There are two forms

shown, the black lines being for a ship with the usual angular bottom and perpendicular sides, and the dotted lines for a ship the sides of which have a "lie out."

Dr. Kirk's block does not approach the form of the actual ship, except in the lengths of entrance, etc., mid-area, and wet surface; but the latter is sometimes as much as 8 per cent. in error, so that it is only useful for similar ships.

In the present block, the lengths and mid-area are similar to Dr. Kirk's, but the wet surface is not taken from the block, but from a diagram of curves which gives the wet surface within 1 or 2 per cent. in every case. The information given in this diagram is taken from a large number of line plans, specially drawn for the purpose by the writer. In order to approximate the shape of the mid-station, the draught, or both the beam and the draught, will be reduced according to the shape. In the case shown in black, the draught only is reduced, and in the case shown in dotted lines, both beam and draught are reduced, the block beam being made a mean between the breadth at the upper turn of bilge and at the load waterline, the draught being made so as to enclose the mid-area. The plan of the block is an approximation of the mean waterline.

The hull, as represented by this block, is composed of two parts, viz., draught and mean waterline, but the latter is itself composed of a number of parts which are studied separately; these are—the length overall, lengths of entrance, run and parallel middle body, and also the angle of entrance. We get the clearest idea of these proportions by measuring the lengths, etc., with the "beam" as a unit of measurement. Thus we say the length is eight beams or six beams; again, we say the length of entrance is two beams or four beams, and so on. Generally, it will be sufficient to consider the mean length of entrance and run, and only in exceptional cases will it be necessary to consider each separately.

Referring to Diagram C (Plate II.), it will be noted that the tangent of the angle of entrance is always ·5 divided by the length of entrance (in beams); ·5, which is the half-beam, remains constant, while the length of entrance alone varies. The length of entrance is the only dimension which entails some difficulty in obtaining, but it will be seen that the mean length of the block is a certain fraction or coefficient of the total, and that the remainder is the length of entrance.

In constructing this block three coefficients are used: (1) block coefficient, (2) mid-area coefficient; and (3) cylindrical coefficient. No. 1 is usually called the coefficient of fineness, but this is a misnomer, as it, alone, gives no idea of the form.

1. Block coefficient $= \dfrac{\text{Displacement in cubic feet}}{L \times B \times d}$. Symbol F.

2. Mid-area coefficient $= \dfrac{\text{Mid-area}}{B \times d}$ . . Symbol A.

3. Cylindrical coefficient $= \dfrac{\text{Displacement in cubic feet}}{L \times \text{mid-area}}$. Symbol C.

Having any two of those coefficients, the third can be readily found. It will be seen from the following proof that $\frac{F}{A} = C$:—

	Displacement in cubic feet	$=$	$L \times B \times d \times F$,
also	do. do.	$=$	$L \times B \times d \times A \times C$,
therefore	$L \times B \times d \times F$	$=$	$L \times B \times d \times A \times C$,
therefore	F	$=$	$A \times C$,
or	$\frac{F}{A}$	$=$	C.

The cylindrical coefficient denotes the fineness of the curve of station areas. It has been shown above that L × mid-area × C = displacement, so of course the mean length of the block must be L × C, and the length of entrance must be L × (1—C). Suppose the length of the ship to be 8 beams and C ·7, then the mean length = 8 × ·7 = 5·6, and the length of entrance = 8 × (1—·7) = 8 × ·3 = 2·4, also the tangent for the angle of entrance $= \frac{\cdot 5}{2\cdot 4}$. The length of the parallel middle body will be 8 — (2 × 2·4) = 3·2 beams.

The mid-area and cylindrical coefficients are those that give the best idea of the form. We can have a direct range of these coefficients, starting from the finest and gradually increasing. If we assume that fine ends and full mid-areas give the best form for speed, and that ·56 is the lowest cylindrical coefficient that should be used, *i.e.*, for a sea-going steamer, then this coefficient will remain constant until the mid-area coefficient reaches ·95 or thereabout, beyond which the mid-area coefficient will remain constant while the cylindrical coefficient will increase to ·9 or more in very full and long ships.

It requires considerable intimacy with the ship's form to realise the fineness or fulness from the general dimensions and coefficients only, or yet when looking at a model, and also to be able to compare one ship with another and decide confidently which is the easier form, especially when the ships have only a slight difference in the proportions of lengths and coefficients, and much time is spent in deciding what ships already built compare most favourably with a new proposal. These difficulties would be completely overcome if we could, as already stated, denote the

value of the form by a single figure. A near approach to this is the set of curves shown on Diagram B (Plate I,), where the proportions of the form are graphically seen the moment the ship is indicated. A single spot indicates one ship; the finest ships are located at the left-hand bottom corner, and the fullest at the right-hand top corner.

On the left hand is a scale of cylindrical coefficients, on the bottom a scale of lengths in beams, on the bottom is also a scale of angles of entrance, which is continued up the right-hand side. An example will best illustrate the application of this diagram. The black spot A indicates a ship having a length of 8 beams, a cylindrical coefficient of ·7, and a block angle of entrance of 11 degs. 45 mins. This angle is found on the diagram by following the curve which passes through the spot until it meets the line marked "centre line;" the other spot B indicates a ship having the same angle of entrance, but the length is only 6 beams, and the cylindrical coefficient is ·6. The draught of the block is the only proportion which is not shown, but this being simply, more or less, a fraction of the beam, can be written beside the spot.

If such a diagram was used in the drawing office it would be advisable to keep separate sheets for each of the different types of ships, such as light draught vessels, tugs and yachts, cruisers, fine merchantmen, tramps, etc. (The scales could be shortened and enlarged to suit the types of ships. Each diagram would be drawn on paper about 2 feet square) These vessels would be permanently marked on their respective sheets, so that we could tell at once what ships to take to base a new proposal on.

Diagram B (Plate I.) shows how the cylindrical coefficient varies with any increase in the length while retaining the same angle of entrance. The mid-area coefficient varies in the same way with any increase in the draught, while retaining the same comparative bilge and bottom. We have in diagram A (Plate I.) a similar set of curves which deals specially with the mid-station.

On the left hand is a scale of mid-area coefficients, and on the bottom a scale of draughts in beams. (These draughts are the actual mean draught of the ship, and not the block draughts.) The right-hand line represents the top of keel. An example will best illustrate the application of this diagram:—The spot A indicates a mid-station having a draught of ·4 beam and a coefficient of ·876; the other spot B is for a station having a draught of ·5 beam and a coefficient of ·9. These two stations have the same comparative bilge and bottom; this is seen on the diagram, because the same curve passes through the two spots. The finest stations are located at the left-hand bottom corner, and the fullest

at the right-hand top corner. Separate sheets of this diagram could also be kept for the different types of ships.

Before passing on to the construction of the line plan, it may be stated that when studying the coefficients the size of the ship should be taken into account, because in small ships the coefficients would be lower than those for large vessels. This will be partly illustrated by Diagram D (Plate I.), where two stations are shown, each having the same proportions. The smaller appears the fuller. This would be more apparent if we were looking at the actual ship. The reason is, being smaller, the bilge has a sharper curve.

Construction.

In constructing the line plan the naval architect has to fulfil the following conditions:—(1) It must have a certain volume of displacement; (2) the centre of the volume must be in a certain longitudinal position; (3) the surface must be "fair;" and (4) the curves ought to be good ship-shape curves.

Let us suppose the dimensions and coefficients as having been decided upon, and all the preliminary lines drawn.

The most important line in the ship is the curve of mean waterlines, this line is also the curve of areas of stations, which means that it is the curve of distribution of displacement, and therefore it ought to be "directly" considered and the "first" line to be designed. The stations being then made to areas taken from this curve.

The side line of the block, as shown on the plan view in Diagram C (Plate II.), is the mean waterline of the block; it also represents the curve of areas of stations drawn to the scale of one-half beam equal to the mid-area, because the stations are rectangular, and the depth is common to all. It follows, then, that if the curve of areas of the actual ship's stations was drawn to the same scale it would practically be the mean waterline of the ship itself.

There are, of course, different opinions as to the correct form of this curve, but there can be no doubt (1) that it is the main feature in the lines, and (2) that all vessels ought to have the same character of curve whether finer or fuller. This cannot be done unless we keep standard curves or tables from which a curve of any area can be taken. The writer of this paper has a set of standard curves which he has used for some years with very great success. He has found that successful lines can be designed for all classes of ships, fine or full, shallow draft, spoon bows, etc., with this "one" character of curve. The usefulness of this set of curves led to their being published in 1896 in the form of tables.

The offsets are given as coefficients of the midship breadth of the curve, and thus are suitable for drawings of any scale. The character of these curves is illustrated by Diagrams E (Plate II.) and F (Plate I.).

In Diagram E (Plate II.) a comparison is made with curves taken from successful and high-class ships. Nos. 1 and 2 are from ships where the cylindrical coefficients are exceptionally fine. Against these is drawn in by dotted lines the finest curve from the tables, which means that a smaller mid-area would be used to get the same displacement. In No. 3 the two curves have the same area, No. 1 is practically the same character of curve as No. 2, but No. 3 is quite different from either Nos. 1 or 2. The writer has found many different curves in use. When not specially considered, it is very easy to alter the character without noticing that you have done so.

In Diagram F a comparison is made with a trochoidal and with a sine curve, No. 1 is a trochoidal, the coefficient being ·5, which the writer considers too fine for a sea-going ship. No. 2 is the finest curve given in the tables, and has a coeffieient of ·56. No. 3 is a curve of sines, while No. 4 is taken from the tables, and has the same area as No. 3

It should be noted that the curve of areas does not end on the perpendiculars. In ordinary merchant ships it would be on the aft side of the stem, and on the rabbet line at the load waterline aft. In a cruiser with a ram bow and part of the stern in the water, it would end at the fore side of the ram, and at the aft end of the stern at the load waterline. It should also be noted that the real length of the ship is the length over the curve of areas. This is the length that is taken for all comparisons and coefficients.

If the centre of this area curve, which is the centre of buoyancy, is to be placed at the half length of the curve, then the same cylindrical coefficient would be used for each end. If the centre is to be forward or aft the coefficients would be different while keeping the same mean as if the centre was at the half length, as given in the writer's tables. This mean coefficient is modified by adding and substracting the quotient $\frac{x + c}{\frac{1}{2}L}$, where x is the distance in feet of the C.B. from the mid length, and c is a constant which varies directly as the ship's length. Its value will be more or less according to the character of curve used ; for that given in the tables, alluded to above, it is ·1 for a ship 100 feet long.

The stations are now sketched on the body plan to the areas taken from the curve. The simplest way to do this is to draw rectangular stations enclosing the areas, then to sketch the curved stations enclosing

the same areas. Diagram G (Plate I.) illustrates the method. Place a tenth scale obliquely across the half body plan, as shown at *a* in No. 1 view, dividing the half breadth into ten parts, and then spot off the mid-area coefficient. A line drawn through this spot will enclose an area equal to the mid-area. Change the scale to *b* position, dividing the mid-area half breadth into 10 parts, and spot off the coefficients of the end stations, these are either read direct from the tables or measured from the curve. No. 1 view shows this rectangular body plan. The curved stations are easily sketched, so that they enclose the same areas. First sketch by hand, as near to the area as the eye can guide (see No. 2 view), trace the part A D L on a piece of tracing paper, and apply this tracing to the part B C D, keeping the pencilled side downwards so as to make an impression on the drawing below, when we trace on the back the part which is taken up F E M, and leaving the part E K M, which has yet to be applied to F C E. The two areas can be made to agree in two or three minutes. It takes about half an hour to sketch in all the stations, *i.e.*, accurately; but if only approximate stations are wanted, it can be done in about 15 minutes, or less. No curves or moulds are used in sketching this body plan. There is usually some requirement in the design which guides the sketching of the stations, such as shape of stern, mid-station, etc.; and, as the stations have a fair curve of areas, it will be found that the surface will be practically fair, and that very little trouble is experienced in completely fairing.

If the fairing lines are taken in the correct order, the line plan will often be faired without rubbing out a line from the half breadth or sheer plan. (Of course to draw like this requires some experience). The reason is that when any one line is faired and the stations modified, keeping the same areas, the surface has three points which are fair, viz. :—(1) Deck or knuckle line; (2) curve of areas; and (3) the line which has been faired. To these may be added the ending of the curve at the keel.

The first line to fair in the fore body is the load waterline. Although the areas of the stations are fixed there is plenty of scope to vary the form of the load waterline, or with one waterline breadth to vary the form of the station, which can be as much V or U shaped as required, we can cut away the deadwood or leave it on. This applies to either the fore or after ends.

There are different opinions as to the form of the load waterline, but whatever the form is, its value is affected by the form of the hull below, for instance, take the two cases shown on Diagram C (Plate II.), they have the same length and the same breadth on load waterline, draught,

displacement, and mid-area. The ship shown in dotted lines is the finer, for, by angling the ship's side the mean beam is reduced, and this reduces also the angle of entrance, because the length of the entrance remains the same; while the stability is practically the same in both cases. This point is worth consideration in designing very fast ships.

The wet surface is a good guide in designing, more especially in fast ships where there are no restrictions on the shape of the stations. If we design a number of line plans, on the same basis, all having the same displacement and dimensions, but different mid-areas, we find that the design with the greatest mid-area has the least wet surface. In lines specially designed for a high speed, the curve of wet surface, *i.e.*, girth of stations, ought to start at each end from nothing and be a fair curve like any other curve in the ship. The writer gives, in his book of tables, a set of curves from which the wet surface can be found for any vessel.

The study of ship's lines is a very interesting one, and becomes much more so when we have some regular method which allows us complete freedom and in no way prevents us from exercising our judgment in all the branches of designing. Having such a standard set of curves as mentioned above, enables us to construct any line plan, direct, without trial and error. If it is desired to use a different character of curve for each of the various types of ships, one can be taken from the tables and be easily modified while keeping the same area; it is better, however, to have only one set of curves, it ensures a certain uniformity, which is very desirable, and will assist in simplifying the problem in connection with propulsion.

The writer intended originally embodying in this paper some ideas and hints for designing and drawing attention to some peculiarities in the form of the hull, but he found that the paper was extending too much, and, perhaps, being complicated, so felt compelled to give it as has been done.

DISCUSSION.

Mr. Edwin W. De Rusett (Vice-President) said he would much rather have waited until some other friend more conversant with this subject had spoken; but he could congratulate Mr. Hogg very heartily on his paper. He did this, not because it was the usual thing; but, having been on the Reading Committee, he had read it with much interest. It evinced much thought and care. He was somewhat surprised at his firm (Sir W. G. Armstrong, Whitworth, & Co., Ltd.,

Walker) letting so much valuable information go out of their office. With regard to the curves, they were exceedingly interesting, and very valuable. He (Mr. De Rusett) had used curves A and B, or very similar ones, for some time. They enabled one's mind to grasp the idea of the fineness of model from coefficients, which otherwise were confusing, and conveyed very little to the mind, as they were affected by the relation of length to breadth, and breadth to draught. By these curves, a naval architect would be enabled to grasp more readily the relation of "block," or prismatic, coefficients of vessels having dissimilar proportions. To give an idea of what he meant, he said his firm had built a vessel having a block coefficient of ·8, and when taking surveyors round the yard had asked them, "What do you think is the coefficient of this ship?" "Oh, about ·75." They were surprised to know it was as full as ·8. They could not get a very good idea of what form a block coefficient represents, until the relation of length to breadth is known and appreciated. In fact, a vessel of 7 beams in length, having a coefficient of ·75, may become a vessel of ·8 if the length is increased to 9 beams by adding parallel middle body, the ends in each case being identical, and, consequently, of equal fineness. Curves of sectional areas were used in his yard when getting out lines, the choice of the curve depending on what the vessel was intended to do, its speed, etc. These curves, of course, represented the whole displacement of the ship, and the relation of the forward to the after body. He could only make a few general remarks, but he would recommend his friends present to keep Mr. Hogg's diagrams by them, and use them. They would be found exceedingly useful, and if any members were more used to the expression "block coefficient" they could very soon construct block coefficient curves for themselves on the same principle.

Mr. Robert Thompson (Past-President) said he wished to catch a train, and was afraid he could not speak fully on the paper at this meeting, but he would like to thank Mr. Hogg for reading so useful a contribution. He was not surprised at his (Mr. Hogg's) firm allowing the information to go out. Similar remarks to Mr. De Rusett's on this point were also made by other gentlemen when he, as President, gave special information to the Institution. People were surprised at it; but he thought it was one of the uses of an Institution of this kind to give information to those anxious to obtain it. They did not want to stop where they were, but wanted to progress, and he was quite sure from the paper they had heard there was sufficient matter to go a step further, probably, than they had been going. He quite agreed with Mr. Hogg in his coefficients. He

was surprised that any one, as remarked by Mr. De Rusett, could not tell the difference between ·7 and ·8, but he would not say if he could tell one between ·75 and ·76 as to which was the finest ship. If they had a sharp bilge they had fine ends, and still the block co-efficient the same. Mr. Hogg had given them tables from which they could choose the form they required, and that was a great matter for young draughtsmen. There was a basis form; but they still had freedom in the design of the ship, and some men were born designers. He was one who believed they had not attained anything like perfection in shipbuilding yet, and such information as they had got from Mr. Hogg would help all of them, viz., those who wanted a perfect form. There were various ideas and opinions as to form, but here they had a system indicated very clearly which showed they could vary form as they liked. If a man choose one form, he could get his dimensions as leading lines and so design his ship. This was what brought them to a better form and got better results in speed and stability. There was only one thing he would like Mr. Hogg to tell them at the next meeting. He says: "The draught of the block is the only proportion which is not shown; but this being simply, more or less, a fraction of the beam, can be written beside the spot." It could be written if they knew it, it did not seem to indicate it. He should like, perhaps at another meeting, to say more upon this paper.

Mr. G. B. HUNTER said he had not heard the paper read. Mr. De Rusett seemed to think himself old-fashioned in the use of certain terms, but what must he be who was so much older, and who could remember the times when the approved practice in designing ships was to erect the midship frame timbers, put on some ribbons from amidships to the stem and stern post, bend the ribbons to the right shape with shores, and make moulds from the ribbons from which to cut out the remaining frames. There was one thing said by Mr. Thompson with which he heartily sympathised, not only as to the desirability, but as to the duty of designers and firms having information that would be useful to other members of the profession to give it out for the benefit of all. He said so for several reasons—first, because it was a duty to the Institution; secondly, because he did not think any of them so very clever as to be exclusively in possession of all valuable information. He thought they could all learn from each other. If one of them had information of great value to himself and others and was willing to make it known for the benefit of all, he was quite sure some other members had information equally valuable, and so were able to reciprocate, and thus No. 1 gets as

much as he gave. Another and a third reason was, he had never found a gentleman clever enough to take any particular and exclusive advantage of information thus given out, and he had never seen information of this kind used in such a way as to make the givers regret having presented their special knowledge to the world at large. They all knew the broad spirit Mr. Thompson had shown, and he believed all the members of that Institution more or less agreed with him and desired to give for all any information they had, a spirit which, he hoped, would always pervade that Institution.

Mr. R. SAXTON WHITE said he did not like to sit still without saying a word of congratulation to Mr. Hogg. There was a great deal of valuable information to be gathered, especially by their younger members, from the interesting paper and diagrams brought forward by Mr. Hogg. He had, of course, naturally watched with very great interest the developments that Mr. Hogg had made in bringing his ideas to their present very complete, accurate, and at the same time simple form. Certainly at first, when in the course of his duty, Mr. Hogg was asked to make preliminary sketches of proposals to fulfil certain conditions, he would produce his little book with its rows of figures, and these, with the curves resulting therefrom, checked by the transferring of one triangle to the top of another, and arrive, within a surprisingly short time, at the required displacement, and at, what was of almost equal importance, the correct position of the centre of buoyancy. He (Mr. White) had certain doubts as to the correctness of calculations arrived at in such extremely short times, but after (and he was speaking not of one case but several) complete designs had been worked out he was very pleased to tell Mr. Hogg and the gentlemen present that as a rule his original figures were confirmed in a remarkable degree by the finished designs. They all had to consider conditions, make proposals, and give quotations very frequently at a very short notice, and if anyone who had that duty to fulfil could bring before them a full set of sections of a ship from which approximate machinery plans could be got ready, so as to be filled in by the engineers with the shortest possible loss of time, this being frequently required to complete a design, it would be doing a good work. Mr. Hogg's system, so fully described in his paper and diagrams, saved them not only a great deal of very valuable time, but by its simplicity made preliminary designs much more correct and reliable than was ordinarily the case with draft designs, with the further great advantage that his system laid down no hard and fast lines restricting the designer in the special requirements of the pro-

posal, but leaving him practically a free hand. He therefore thought the working out of such an elaborate and exact system, simple and free as it undoubtedly was, to a degree, did Mr. Hogg considerable credit. He knew the immense amount of work and trouble he had taken to bring this information into such a form that "those who run may read," the general principles underlying and governing his tables and diagrams, and he thought the Institution as well as Mr. Hogg might be congratulated upon the information thus afforded to its members.

Mr. GEO. N. ARNISON said he had listened with great pleasure to the reading of the paper, although having had one of Mr. Hogg's books in his possession the topic was not altogether new to him. He would recommend anyone who had not a copy of Mr. Hogg's *Tables for Constructing Ships' Lines* to get one and study it along with this paper. Certainly, for young draughtsmen it was most instructive. Mr. Hogg had reduced to a system the designing of a vessel. A quarter of a century ago it would have taken a couple of days to do what now could be done in a few hours by the process laid down in Mr. Hogg's paper. He had no words of criticism to offer in regard to the system, because he did not see how it could be improved upon. It gave elasticity and enabled every designer to follow his own ideas, and thus recommend itself to all naval architects. He did not know whether he should mention another matter while on his feet, but they all had participated in the President's very kind hospitality the other evening, and he thought it was their duty at this the first regular meeting of the session to acknowledge his kindness, and he felt it to be a privilege to propose a very hearty vote of thanks to him. He believed the attendance was a record one, it seemed to be so, the rooms were fuller than on any previous occasion, which showed how much they respected their President. Further, he was sure they all enjoyed themselves.

The SECRETARY (Mr. Duckitt) put it to the meeting, and the vote was accorded by acclamation.

Mr. J. R. FOTHERGILL (Vice-President) said that in rising he wished rather to make an appeal to Mr. Hogg in regard to what he thought would be of great value and benefit to this Institution. The general expression of opinion was that Mr. Hogg's paper was of very great value, which he fully endorsed. He could not help noticing that Mr. Hogg, after he had read the paper, expressed regret that he had had to condense it into so short a space—afraid lest he should make it too long,

otherwise he would have given practical illustrations exemplifying his statements. He appealed to him to give them this additional information as an appendix, and in doing so he could feel assured it would be fully appreciated by the members of the Institution.

The PRESIDENT said he was taken rather aback by the proposal made by Mr. Arnison—he thought they were in the middle of a discussion on the paper. He was put in a difficulty, hardly liking to rule him out of order. He could only say that if Mr. Arnison and all others who favoured them with their company the other night enjoyed themselves that that was the greatest possible satisfaction he could have. He thought that even in a scientific institution it was well to have a social side, and by reunions of that kind people got to know each other, whereas otherwise they might not have the opportunity. They might know each other by name, or they might be celebrated men whose names were well known to them, but whom they never happened to come across except on an occasion of that kind. It brought people together from a distance, and was, therefore, a useful change from the more serious part of the Institution. If, as he had said, the last conversazione was satisfactory and pleasant to them all, he was sure it was the greatest recompense he could have to hear them say so. As regarded the paper by Mr. Hogg, it was of the kind that were specially valuable to the Institution. He supposed they could not pretend that they all followed these scientific subjects from a love of science itself: they wanted it for a practical purpose and to apply such ideas as were promulgated there to their daily avocations, and anything that enabled them to do that in a thoroughly practical way must really commend itself to them. He was quite sure that this graphic mode Mr. Hogg had shown for designing a ship would be a saving of a very great deal of time and reduce, as it were, the designing of vessels to a system. They all knew that in these days they had to make any number of designs and calculations for ships that were never built, and it became a very serious tax when they had to expend many days, perhaps, in designing a vessel and nothing came of it. When they could get a graphic way of arriving at results in an hour or two which would otherwise have taken several days, that was a practical outcome of meetings of this kind which could not fail to be of use to them all.

The discussion at this stage was adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897-98.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUNDERLAND LITERARY SOCIETY, SUNDERLAND, ON MONDAY EVENING, 6TH DECEMBER, 1897.

J. R. FOTHERGILL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

The VICE-PRESIDENT said they would much regret to hear the President (Col. H. F. Swan) was unable to attend the meeting owing to a slight cold. He hoped in a few days to be quite well again.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on 5th November, 1897, which were approved by the members present and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Prof. R. L. Weighton and Mr. H. Fownes to examine the voting papers, and the following gentlemen were elected :—

MEMBERS.

Carter, Geo. J., Naval Architect, Elswick Shipyard, Newcastle-upon-Tyne.
Neill, William Reid, Engineer Draughtsman, 15, Salem Hill South, Sunderland.
Reed, James, Ship Draughtsman, Messrs. Palmer's Shipbuilding and Iron Company, Limited, Jarrow-on-Tyne.
Tinn, George, Superintendent Engineer, 205, Coatsworth Road, Gateshead-on-Tyne.
Todd, John P., Engineer Draughtsman, 13, Chatsworth Street, Sunderland.

GRADUATES TO MEMBERS.

Adams, Dawson, Electrical Engineer, c/o Messrs. The National Electric Supply Company, Limited, Bushell Street, Preston, Lancashire.

Cadman, C. C., Engineer, Clifton Holm, York.

Cairns, C. W., Engineer Draughtsman, Cheriton House, Lothian Road, West Hartlepool.

Gibson, Thomas, Marine Engineer, 162, Roker Avenue, Sunderland.

Pearson, James T., Ship Draughtsman, 11, Beech Grove Road, Newcastle-upon-Tyne.

Smith, Wm. Stuart, Ship Draughtsman, West Villa, The Green, Wallsend-on-Tyne.

Willcox, R. J. N., Engineer, c/o Mrs. Stafford, 15, Lennox Street, Middlesbrough.

ASSOCIATE.

Park, Robert, Accountant, Lauriston, Blackhill, Co. Durham.

GRADUATES.

Canning, Chas. E., Ship Draughtsman, 31, Park Crescent, North Shields.

Craggs, Adolphus, Engineer Draughtsman, Ivy House, Pelton, Chester-le-Street.

Thomas, John P., Apprentice Engineer 6, Queen Anne's Terrace, Gateshead-upon-Tyne.

Watson, John, Ship Draughtsman, 108, Meldon Terrace, Heaton, Newcastle-upon-Tyne.

COUNCIL MEMORANDUM.

The VICE-PRESIDENT said he was sure they would be pleased to hear that the Right Hon. Lord Hopetoun, President of the Institution of Naval Architects, had accepted the invitation of the Council to become an Honorary Member of the Institution.

GOLD MEDALS.

The VICE-PRESIDENT said it was his pleasing duty to present the gold medals to the recipients. The memorandum of agreement between the donors of the gold medals and the Institution stipulated that the medals must be given for papers upon marine engineering and shipbuilding subjects only. The Council ruled Mr. Morison's paper on "Gravitation Stamp Mills" was disqualified.

The engineering medal for last session was awarded to Professor R. L. Weighton, M.A., for his paper on "The Experimental Engines at the Durham College of Science, with some results from same." He had very great pleasure in handing to Professor Weighton the gold

medal. He felt sure they would all agree with him that the paper given by the Professor to that Institution was one of exceptional value, and one from which not only the members but the whole engineering world would derive great benefit. The donors of this engine must feel considerable satisfaction in the valuable information the Professor had been able to give, and no doubt they realised the gift of the experimental engine was not only a useful and necessary requirement of the college but a sound investment. He hoped the Professor would, in the near future, give them a continuation of his paper, as he was sure they all anxiously looked forward for the results of additional experiments.

As no medals were awarded in 1895 the Council agreed to award another medal to Mr. R. Wallis for his paper read last session on "Liquid Fuel." In handing the medal to Mr. Wallis, he felt sure the members would agree with the decision of the Council. Those who had read that paper must admit that it was a most able and instructive paper, and that Mr. Wallis thoroughly deserved the medal awarded him. He desired to congratulate both gentlemen on this distinctive recognition of their ability, and hoped it would be an incentive to greater achievements in future.

He particularly regretted the President was not present to present the medals, for he looked upon it as one of the pleasures as well as one of the duties of his office. He hoped the recipients would appreciate them none the less for having received them at his hands.

The discussion on Mr. Archibald Hogg's paper on "The Comparison and Construction of Ships' Lines" was resumed.

Mr. C. H. INNES read a paper on "The Theory of the Centrifugal Pump and Fan."

DISCUSSION ON MR. ARCHIBALD HOGG'S PAPER ON "THE COMPARISON AND CONSTRUCTION OF SHIPS' LINES."

Mr. J. KING said the interesting paper read by Mr. Hogg was a very valuable one in many respects; but he thought that the system of comparing and constructing ships' lines, as described therein, fell short in some respects of what it should be to attain general application, and of what the author would, doubtless, like it to be. Mr. Hogg said, in the opening part of his paper, that "if the value of a ship's form could be denoted by a single figure," etc. No doubt; but he (Mr. King) did not think it was possible to completely denote the value of a ship's form by a single figure, because there were several varying elements that entered into and affected the value of a ship's form for comparison and efficiency which could not be well expressed in a single figure, nor by a single diagram. Indeed, the Diagram B (Plate I.), which Mr. Hogg had prepared, was a very ingenious method of expressing certain qualities of the ship's form by a single diagram; but there were certain things entirely left out, as, for example, relation of draught to beam, proportion of length of entrance to that of run, position of centre of buoyancy, etc., which were important things to indicate, and necessary, in his estimation, to fully express or indicate a ship's form. Mr. Hogg had claimed for his system that it was one by which they could design a set of line plans without trial and error, but further on he explained how he obtained the body plan, and as far as he (Mr. King) could make out, it was, at least to some extent, a system of trial and error. If one was expert at this particular thing, one might get very quick at sketching the curved outline of a certain figure of given area to fulfil the conditions of fairness, etc.; but that expertness, he should think, could only come by long practice. The spot on Diagram B would not truly indicate the character of the vessel's form unless the centre of buoyancy was at the ship's mid-length, which it might or might not be, because the "angle of entrance" shown on the diagram was the approximate mean angle of entrance and run, and therefore might not truly indicate the actual angle of entrance. He (Mr. King) thought the expression "angle of entrance," on the diagram, was rather misleading. The Diagram B did not provide for the proportion of draught to beam. Mr. Hogg said that that proportion can be written beside the spot on Diagram B; but when comparing one ship with another by this method, unless that proportion was the same, or nearly so, the similarity of form

would be more apparent than real, for a dissimilar proportion would affect the character of the vertical disposition of displacement; and in comparing ships the vertical distribution of displacement was just as important as the distribution longitudinally. Taking an extreme case, for example, and comparing by this method a very deep ship of the same beam and coefficients as a very shallow ship, and they would appear similar, but in reality the forms, in comparison and power-efficiency, would be quite different. Indeed, as Mr. Hogg pointed out, in the ship with a fall-out side, in Diagram C (Plate II.), and comparing that with the ship with perpendicular side, the form of those two vessels would be totally different, although in the diagram they would appear to be somewhat similar. Then as to the "angles of entrance" on Diagram B, and taking an example of two ships, with similar proportions and co-efficients, one with the centre of buoyancy at midships and the other well aft, the spot on this diagram would indicate the vessels as identical, whereas the forms would be very different indeed, and the propulsive efficiency of those two ships would probably be different. He (Mr. King) thought the position of the centre of buoyancy should be written alongside of the spot in terms of the length. There appeared to be a slight inconsistency on page 19 of the paper. Mr. Hogg said: "There are, of course, different opinions as to the correct form of this curve" (speaking of the mean water-lines), "but there can be no doubt (1) that it is the main feature in the lines, and (2) that all vessels ought to have the same character of curve whether finer or fuller." It did not seem to him to be quite clear how and why vessels must have the same character of curve, no matter whether the vessels were finer or fuller. He should like Mr. Hogg to make that point clear in his reply. Then another point was as to the length he took for the curve of mean water-lines. In a merchant vessel, he said, it would be on the "aft side of the stem and on the rabbet line at the load water-line aft. In a cruiser, with a ram bow and part of the stern in the water, it would end at the fore side of the ram, and at the aft end of the stern at the load water-line." So far as the stem was concerned not much error would be made in this, because usually in a merchant vessel the stem was vertical, or nearly so; but in way of the propeller aperture the error might be considerable, for the end of the load line might be on the aft post, and on another, but nearly similar ship, might come on the forward post, thereby probably making a difference of 5 feet or 6 feet in the apparent length. Now, with that difference in the virtual length of the two ships' block models, they would get a different form in mean water-lines, and it would also

affect, at least to some extent, the apparent angles of entrance and run. To design a vessel on Mr. Hogg's system, it seemed to him that an important point, at the early stages of the work, would be to fix the position aft, where the load water-line would end. Then the length of warships would be taken as the extreme length, that was from fore side of prow to aft side of counter on the load line. He did not think that would be a fair comparison, because the prow and the counter, he thought, ought to be treated as appendages rather than as the main body, otherwise some warships would appear, in comparison with others, longer than they really were. Outside of the perpendiculars, the appendages did not affect the form of the vessel to any serious extent. He pointed these things out to indicate that the length he (Mr. Hogg) took seemed to him to be a weak point of the system. The constant for regulating the position longitudinally of the centre of buoyancy was not very clearly explained, and he (Mr. King) would like to know how he arrived at it. In comparing ships' lines he did not think Mr. Hogg's system took into sufficient account the effect of the position of the centre of buoyancy longitudinally. The position of the centre of buoyancy in some particular classes of ships was rather important. Take paddle steamers, for instance: the centre of buoyancy was almost invariably aft (and sometimes well aft) of midships, and in a comparison the effect produced by this on the vessel's lines should be made evident. He thought few draughtsmen could design a ship's form to satisfy the necessary conditions quite so quickly as Mr. Hogg claimed for his system. But he also claimed for the system complete freedom in the designing, laying down a condition, however, that they must have standard tables before they could proceed—which he (Mr. King) thought was rather inconsistent with complete freedom of design. The chief value of the method, as far as he could make out, was the rapidity with which a design of a set of lines might be made, and frequently it was an important thing to get out the first set of lines quickly; but beyond that, he did not think it would tend to improve vessels' lines, unless the standard curves were the best possible. There were other methods, of course, which had been designed to do what Mr. Hogg aimed at, namely, to simplify the first operation of designing, and to arrive at a certain displacement within given dimensions and to make a fair ship's surface in a short space of time. There was a very neat method of recording and comparing ships' forms he had seen applied, and which was described in a paper read about twenty-five years ago in Glasgow, before the Institution of Shipbuilders in Scotland, by Mr. Mansel. It was a very simple method, by which they could record the

form of any vessel. He described it as a method for reducing the body plan sections to the decimal system. A ship's length would be divided into ten sections, and the half-breadth was reduced to ten quarters—to a quarter-inch scale—and the moulded depth was in terms of the ship's breadth; so that within a very small compass one could have a great many forms of different vessels, and it was an exceedingly simple matter to strike out the lines of another similar vessel which might be adopted from a previous successful ship of the same character by reading the offsets on those decimal lines. There was also a system of coefficients, so that it could be seen at once whether the proposed type of vessel had the desired form for displacement, etc., or not.

Mr. Robert Thompson said he had had a comparison of lines made from Mr. Hogg's totals, and compared them with some ships they had built, the results of which would be found in Plates III. and IV. The idea of the construction of these curves was very good, and, in his opinion, was a step in the direction in designing vessels so as to ensure some similarity in the forms which had given a good performance of steaming and sea-going qualities, and, at the same time, a shapely model. He had tried several vessels built by this firm of various coefficients which had given very good results as regards cargo capacity, and speed, and sea-kindliness, and he found Mr. Hogg's curves would make the vessels very much fuller on the shoulders and finer at the extreme ends, in other words, a tendency to give the vessel hollow water-lines fore and aft, and in case of vessel ·82 block coefficient, the largest section would appear to the eye to be at the shoulders instead of amidships, and in case of a very fine vessel built by their firm it would have reduced the lines at the end of the vessel to such an extent that there would have been considerable difficulty experienced in riveting at these parts. Of course, Mr. Hogg gave the designer the option of modifying the curves according to his ideas; this seemed to dispense with the utility of Mr. Hogg's curves, because the principal feature in designing was to get the shape of the curve of areas of immersed sections, and to shape the transverse section so as to embrace its respective area, and also to maintain the fairness and uniformity of the lines to get a shapely model. Mr. Hogg seemed to undertake a good deal of work when he spoke of designing a curve of sectional areas and shape of sections, and, at the same time, get the lines fair and uniform, so as to estimate quantities of material and capacity. In the matter of co-efficient the writer seemed to have a standard coefficient for amidships

area. This could not always be relied on as care must be used in shaping the amidships section of the vessel to get the best value out of Lloyd's grades, at the same time getting full value from such dimensions.

Prof. R. L. WEIGHTON said the last two speakers, he thought, had devoted themselves chiefly to the second part of what he took this paper to deal with, namely, the construction of ships' lines to secure certain qualities in the shape of buoyancy, stability, etc. He should deal principally with the first part, which was the comparison of different forms as shown in Diagram B (Plate I.). Referring for a moment to the second part of the paper, the author endeavoured to deduce or construct lines from certain elementary data—length, breadth, draught, displacement, and immersed mid area. He (Prof. Weighton) must say that he sympathised with Mr. Hogg in the criticism to which he was sure to be subjected, because to deduce general methods from particular data was always a very difficult matter, as all knew who had tried it, and any man could criticise such an attempt with considerable success, for it was quite impossible to make any general method cover all particular cases in practice, and this, he thought, in criticism ought to be borne in mind. He (Prof. Weighton) had derived considerable instruction from the perusal of this paper, and particularly from the first part; he was not, however, altogether satisfied with it any more than Mr. Thompson or Mr. King was with the second part.

Mr. THOMPSON—Allow me. I think the criticism of a paper is the value of it. If a paper is not worth criticising there is no value in it. As I spoke at the last meeting in favour of the paper, I thought it was an advantage to give these actual results and secure Mr. Hogg's reply, so that the discussion and the paper might make a very valuable contribution to the *Transactions*.

Prof. WEIGHTON (continuing)—With regard to the comparison of ships' forms, this was an attempt to indicate *type* of ship by a graphic method. The basis of the method was practically what was known as "Kirk's block," with a small modification, viz., changing or varying the depth of the block instead of the breadth of the block. Kirk's block was a figure composed of straight lines and plane surfaces, having the same length, depth, mid area, and displacement as the actual ship. The author's block was a similar figure, only instead of varying the breadth he varied the depth in all cases, except as shown in Diagram C (Plate II.).

In varying the depth, he (Prof. Weighton) thought he had made a slight improvement; because he got on the whole a nearer approach to the mean water-line of the actual ship. But the difference between the two blocks was very small indeed, except in ships with great rise of floors and very large curves of bilge. If both breadth and depth of block were varied, the method would be very much limited in general applicability; because, in the case of any ship whose lines or midsection was not before one, it would be impossible to tell how much to vary each. Looking at it from the point of view of the estimator of speeds and powers, he submitted they must have some method to enable them to analyse the ship's form for the purpose of comparison without having the ship's lines before them. However, he thought there could be no doubt that in varying the depth of the block instead of the breadth, a slightly nearer approximation to the mean water-line or angle was got, but no nearer approximation to the wetted surface was secured, and the writer said Kirk's block did not indicate the wetted surface nearer than 8 per cent. In his (the speaker's) experience the actual surface differed from the block surface to the extent of from 2 to 15 per cent., according to the type of ship, and the writer's block would differ practically the same, so there was no argument in its favour from this point of view. Most ships had got vertical sides—(Mr. Thompson—"And flat bottoms") —and therefore he (the speaker) thought the method of varying depth alone preferable, breadth being the same as ship's beam. The writer seemed to make a great point of the difficulty of obtaining the lengths of entrance and run of the block, and said they needed to use three co-efficients. They did not need to use any coefficients at all, it was a simple matter of geometry. Take Mr. Hogg's block. They were given the length, beam, draught, immersed mid area, and displacement, and from these they could produce the block thus, using Mr. Hogg's symbols, Let E = absolute length of entrance or run, then $\frac{\text{mid area}}{B}$ = depth of block.

$$(L - E) \text{ mid area} = 35\ D,$$

$$\therefore\ E = L - \frac{35\ D}{\text{mid area}},$$

and the tangent of the half angle of entrance or run was $= \frac{B}{2E}$. Now, with regard to the comparison of ships' forms embodied in Diagram B, he thought this very ingenious and likely to be very useful in a certain way; but he thought the omission of the draught was a great defect. In the third and last paragraph of the paper the writer instanced the two

cases shown on Diagram C (Plate II.), and said :—"There are different opinions as to the form of the load water-line ; but whatever the form is, its value is affected by the form of the hull below, for instance, take the two cases shown on Diagram C, they have the same length, breadth on load water-line, draught, displacement, and mid area." Nothing differs in these two cases but the *shape* of the mid area. But, owing to the writer diminishing the breadth of the block in the one case and not in the other, he necessarily got rather a finer water-line for the block of the former than for the block of the latter, and from this he concludes the former ship is the finer, and presumably would therefore be easier to drive, "for by angling the ship's side the mean beam is reduced." But how did they know the angle of the block thus obtained was the true mean angle of the actual ship? All through this part of the paper it appeared to be tacitly assumed that the block angle was the true index of resistance. He (the speaker) would be inclined to doubt that very much, particularly in regard to the cases just cited, where the differences were so small. He wished to ask the question if the draught in Diagram B (Plate I.) referred to the ship or to the block?

Mr. Hogg—It is the draught of the block.

Prof. Weighton said he had taken it to mean "draught of the ship." Taking it as draught of block, however, the author was quite consistent. From the point of view of the estimator of powers and speeds—which he took to be the theme of the first part of the paper—the comparison of types of ships was of some assistance as far as the eye was concerned; but in thinking it over he did not see it was of very great assistance really, because although they could locate the positions on Diagram B of any number of types of ships, what was there in that to guide the speed estimator in his choice of coefficients of performance if he had no results from a ship of the particular type engaging his attention for the movement? The author seemed to consider the curve of angle of mean water-line as a better index of relative resistance than anything else. He (Prof. Weighton) did not know whether Mr. Hogg really meant that or not, but he gathered he inclined that way. If he (the speaker) was wrong in his reading of the paper in this respect, he hoped Mr. Hogg would put him right in his reply.

COMMUNICATION FROM Mr. A. E. LONG.

JARROW,

December 2nd, 1897.

DEAR MR. DUCKITT,

Having very carefully read over Mr. Hogg's interesting paper I wish to make a few notes for the adjourned discussion.

Probably no one will dispute Mr. Hogg's statement that the curve of sectional areas is the most important line in the ship; that is proved by the fact that the use of such a curve is about 100 years old, or possibly more, and has been used by a great many designers and writers upon the subject since. The chief merit of such a curve as a basis is, that it keeps us in touch with actual ships whose performances are known, that is, if the curves used are taken directly from previous designs. If we use a set of arbitrary curves, such as Chapman's, Nystrom's, Hogg's, etc., a good deal of the merit of the method disappears, and it is reduced merely to a mechanical method of getting a given displacement. In this light the author's method is no better than several others which are simpler, and give as good results.

One of these old methods, revived by Mr. Ramage at the Institution of Naval Architects this year, is a mean water-line, but, as Mr. Ramage admits, it does not allow for differences in the form of bilge, etc. Mr. R. Zimmerman's bilge diagonal method (*Institution of Naval Architects*, 1883) gets over this difficulty, as it cuts the bilge, and is really, as he shows, a species of curve of sectional areas. An advantage which this method has over a true curve of areas method is, that it gives an actual "spot" in each section near its middle, thus there are three spots for the curve, rail, or knuckle, diagonal, and on the base line. I have used this method for ordinary cargo vessels ever since 1883, and have found it both as accurate, and much more rapid than any other method that I have tried. The only calculation required to use it is the simple prismatic coefficient.

For high speeds all these mechanical methods fail, as they do not tell us directly how the curve we are using compares with previous experience. For this purpose the curve of an actual high speed vessel is really a more satisfactory basis, as we can see how far our modifications are likely to lead us from a known good vessel.

Mr. Hogg does not tell us how his standard curves are calculated, whether they are similar to Chapman's and Nystrom's, or obtained by some new method; it would add to the value of his paper if he gives us this information in his reply.

I cannot quite follow the statement "that all vessels ought to have the same character of curve." The curve of a five beam cruiser seems to me to differ greatly from that of an eleven beam destroyer, or an Atlantic liner; perhaps Mr. Hogg uses the word "character" in some peculiar sense.

As to details, I do not think that the proposal to use the extreme length of a warship, fore side of ram to after side of counter, is an improvement upon the Admiralty length between perpendiculars. If we take the lines of a cruiser, say, and for some purpose add 2 feet to the outreach of her counter, the actual difference in displacement, centre of buoyancy, etc., will be trifling; but for recording in a table like Mr. Hogg's we would have to respace our ordinates, and the figures would lead anyone to suppose that the vessel had been altered all fore and aft. Much the same thing applies to the rather indefinite point which he takes aft in a merchant vessel. The method of getting the correct areas by first drawing rectangles, and then going through some sleight-of-hand business with a piece of tracing paper, does not seem to be as rapid or neat as the more ordinary method of trying the area with a planimeter.

Being very much interested in the form of high speed ships, I have read over the note upon the value of flaring sides repeatedly, but cannot grasp the author's meaning; he claims that the flaring sided vessel is the finer. If the length and mid area are the same, also the displacement, the prismatic coefficient must be the same. If the draught and mid area are alike, so also must the mean breadth of the midship section; and very much the same applies to all the other sections. How, then, the one vessel can be finer than the other, except by some subtle jugglery of Kirk's analysis, I cannot conceive. Perhaps, as there may be other puzzled persons in the Institution, Mr. Hogg will explain.

These mechanical methods of getting a desired displacement, do not in themselves tend to the improvement in the form of ships directly, but indirectly they do so, as they allow the designer to use his whole available time in putting the displacement into the best possible shape, instead of by the old system spending the greater part of it in frantic attempts to get the required volume. For this reason alone I think that our thanks are due to Mr. Hogg for putting our very old friend, the curve of sectional areas, into a fairly convenient form for ready use.

I fear that the interest of the subject must be my excuse for the length of this letter.

Yours faithfully,

A. E. Long.

The discussion was adjourned.

THE THEORY OF THE CENTRIFUGAL PUMP AND FAN.

By C. H. INNES, M.A. (Cantab.).

[Read before the Institution, in Sunderland, December 6th, 1897.]

It is with considerable hesitation that the writer offers to such an exceedingly practical Institution of engineers a paper of a theoretical nature. As, however, the theory discussed in the following pages is amply supported by experiment, and as it deals with the proper design of such pumps and fans, it may possibly be of some interest.

In Figs. 1 and 1[a] (Plate VII.) are shown two sectional elevations of a centrifugal pump. The water enters at A, passes on both sides of the pump to B, where it enters the fan. In this it receives an increased tangential velocity. After leaving the fan it enters the diffuser C, where, owing to the increasing radius, its kinetic energy is partially converted into pressure energy. It is then received by the volute, a spiral whose section increases with the angle measured from a radius passing through E—that is, if the diffuser is bounded externally by a cylindrical surface; but if the diffuser has a spiral surface, the section of the volute increases more rapidly according to a law which will be explained in connection with the Rateau pump and fan. In the former case the velocity at discharge is the same as the tangential velocity on leaving the diffuser; in the latter, it is the same as the tangential velocity on leaving the diffuser at the point nearest to the discharge. The velocity may be further reduced by a conical discharge pipe.

This contains all the elements of a centrifugal pump. Many, indeed most, are without the diffuser D, and the fan in some cases, instead of being open at the sides, has conical sides, and frequently discharges into the centre of the volute. Some few pumps have a vertical axis for symmetry, but a horizontal axis is the rule.

In designing a pump the following qualities should be aimed at:—(1) High efficiency; (2) volumetric power, which may be measured by the quantity that it will discharge at maximum efficiency against a given head.

The former must be attained by minimising the losses of energy, as the efficiency may be expressed by the fraction, $\frac{H}{H + L}$, where L is the

loss of energy undergone by each pound of water in foot-pounds—*i.e.*, the loss of head, and H the head in feet.

Losses of Energy or Head.—These losses occur in the following order:—(1) Loss at inflow caused by the edges of the vanes and sudden change of direction. This latter is expressed by equation (1), and equation (2) expresses the condition that this loss shall be avoided.

After leaving the fan, and supposing there is no diffuser, and that the discharge takes place into a volute in which the velocity is v_4 (Fig. 2, Plate VI.), the direction Av_4 being nearly tangential, then the loss of head is $\frac{vv_4^2}{64}$, and will be least when $(vv_4) = (vw_1) = u_1$, or when $v_4 = w_1$, the velocity of whirl or tangential component of the velocity at discharge from the fan. The loss of head is then expressed by equation (3), where u_1 is the radial component of the velocity of discharge from the fan; but, under these circumstances, the discharge from the pump will take place with a high velocity w_1, and there will be an additional loss, which can be best prevented by using a conical discharge pipe in which the velocity is reduced to some small value D, which in practice is as low as 2 feet per second. The additional loss of head is then given by equation (4). If such pipe is not used, the total loss of head caused by shock on entering the volute, and by the waste of kinetic energy at discharge, will be given by equations (5) and (6), and its minimum value is obtained by making $(Av_4) = (v_4w_1)$, when the velocity v_4 in the volute is half the velocity of whirl from the fan, and the loss under these circumstances is given by equation (7). It is unnecessary to consider the case where there is no volute or diffuser, as the efficiency of this type of pump is very low.

If, however, there is a diffuser surrounding the fan with constant breadth, the velocity is reduced inversely as the radius, equation (8). On entering the volute the loss of head is therefore very much less, and is given by equations (9*a*) and (9*b*). In addition to the above, there are the unavoidable losses due to bends and surface friction. As far as the water discharged through the pump is concerned this may be expressed by equation (9*c*). There is another resistance that takes power from the shaft. In encased fans the resistance varies as c_1^2 and, as the motion of the outer surface of the fan varies as c_1, the amount of work required varies as c_1^3, but this is a small quantity of work compared with the total work done by the pump, except at small orifices, when it is of small importance in calculating the efficiency, and except at small orifices it is neglected in what follows; it does not affect equation (14). If the wheel is not

encased at the sides the particles of water rubbing against the casing are opposed by forces proportional to the squares of their absolute velocities; the work done on them is proportional to the cubes of their absolute velocities, and at small orifices this is nearly proportional to the cube of the peripheral velocity of the fan. At any orifice this compels the shaft and fan to do more work than $\frac{c_1 w_1}{g}$ per lb. of water passing through the fan, because the change of the moment of the momentum is equal to the moment of the impulse of the external forces as explained in Appendix A, and the friction of the casing has a moment opposing the moment of the fan and shaft. This, however, may be neglected, except at small orifices, when it affects equation (12), but not equation (14). If the pump discharges through a length of piping, the loss of head may be calculated by some pipe friction formula. There are several of these, and all give different results; in this paper D'Arcy's formula has been used and is given in equation (10*a*). For bends, Weisbach's formula may be used, equation (10*b*); and, lastly, there is the friction of the bearings, which cannot be expressed by any known formula. Excluding this last, which is small, the hydraulic efficiency is:—

$$\eta = \frac{H}{H + L} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

List of Equations:—

$$L_1 = \frac{(c_2 - u_2 \cot \theta)^2}{2g} \quad . \quad . \quad . \quad . \quad (1)$$

c_2 = velocity of fan at inner radius.

u_2 = radial velocity of water at inflow.

$$c_2 = u_2 \cot \theta \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Condition, that L_1 should be zero.

$$L_2 = \frac{u_1^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where u_1 is the radial component of the velocity at discharge.

$$L_3 = \frac{D^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where D is the velocity of discharge from the end of the conical discharge pipe.

$$L_4 = \frac{v_4^2}{2g} + \frac{(vv_4)^2}{2g} \quad . \quad . \quad . \quad . \quad (5)$$

$$= \frac{v_4^2}{2g} + \frac{(w_1 v_4)^2}{2g} + \frac{u_1^2}{2g} \quad . \quad . \quad . \quad (6)$$

$$= \frac{w_1^2}{4g} + \frac{u_1^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where w_1 = tangential velocity at discharge from the fan.

$$\left.\begin{aligned}\frac{w_8}{w_1} &= \frac{r_1}{r_8}\\ \frac{u_8}{u_1} &= \frac{r_1}{r_8}\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$L = \frac{u_8^2}{2g} = \frac{u_1^2}{2g}\left(\frac{r_1}{r_8}\right)^2 \quad . \quad . \quad . \quad . \quad (9a)$$

$$L_7 = \frac{w_8^2}{4g} + \frac{u_8^2}{2g}$$

$$= \left(\frac{w_1^2}{4g} + \frac{u_1^2}{2g}\right)\frac{r_1^2}{r_8^2} \quad . \quad . \quad . \quad . \quad . \quad (9b)$$

where w_8, u_8 are the tangential and radial components of the velocity of discharge from the diffuser

$$L_8 = \frac{Bv_4^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9c)$$

$$L_9 = \cdot 01\left(1 + \frac{1}{12d}\right)\frac{4l}{d}\frac{v^2}{2g} \quad . \quad . \quad . \quad (10a)$$

where l and d are length and diameter of pipe in feet and v = velocity of flow in feet per second

$$L_{10} = \left[\cdot 131 + 1\cdot 847\left(\frac{d}{2\rho}\right)^{\frac{1}{2}}\right]\frac{v^2}{2g} \quad . \quad . \quad (10b)$$

where d and ρ are the diameter of pipe and mean radius of bend respectively.

All the above losses may be expressed in the form $c_1^2 + mc_1v_4 + nv_4^2$ where m and n are constants.

Again, $$\eta = \frac{gH}{c_1w_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where w_1 is the tangential component of the velocity of the water at discharge from the fan, because $\frac{c_1w_1}{g}$ is the work done by the fan on each pound of water, hence

$$\frac{c_1w_1}{g} = H + L \quad . \quad . \quad . \quad . \quad . \quad (13)$$

and a relation or equation between c_1, H, and Q the number of cubic feet per second may be expressed thus :—

$$c_1^2 + pc_1Q + qH + rQ^2 = 0 \quad . \quad . \quad . \quad (14)$$

because Q varies as v_4; this equation is also true for a fan.

It follows from this that at a given orifice, *i.e.*, if $\frac{Q}{\sqrt{gH}}$ = constant

$$c_1 \propto Q \propto \sqrt{H} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

and the hydraulic efficiency is constant at that orifice whatever be the head.

Hence, in all diagrams relating to pumps or fans, it is convenient to take the orifices as abscissæ, so that experiments made at different heads may be combined in one diagram.

Manometric Power or Efficiency.—This is measured by the fraction $\frac{gH}{c_1^2}$, a high manometric power at a given head, meaning that the peripheral speed at that head is small; and it will be seen by (15) that the manometric power for a given orifice is a constant quantity both for pump or fan; the manometric power for pumps having the same efficiency depends on the angle that the mean relative outflow from the disc makes with the tangent to the circumference of the fan. If it is backwards, as in Fig. 3 (Plate VI.) w_1 is less than c_1, and the manometric power is less than the efficiency. If the angle of relative outflow is radial, then w_1 is equal to c_1, and the efficiency equals the manometric power; but if the angle of relative discharge is forwards, the manometric power is greater than the efficiency. It will be noticed that the term, "angle of relative flow," and not "of vane" is used, because these may not coincide at outflow owing to the curvature of the vane, and the space between two vanes. In what follows the three types of vanes corresponding to these three directions of discharge will be named Appold, Rankine, and Rateau vanes, the last type being used in the pumps and fans designed by Prof. Rateau. Now, while in the fan, it is a great advantage to reduce the peripheral velocity c_1, owing to the fact that the heads against which a fan works are invariably very high, *e.g.*, a depression of 1 inch of water corresponding to a head of air of about 70 feet; in a water pump the type of vane, whether Appold or Rankine, depends solely on the sort of engine, whether low or high speed, that is preferred, because at the present day equally good low and high speed engines can be constructed, and there is nothing to show that one type of vane will give a higher efficiency than another. Thus, in the pumps constructed by Messrs. Farcot for irrigation at Khatatbeh, Egypt, these having Rankine vanes, the manometric power is ·659, and the number of revolutions per minute is 34, the efficiency claimed being ·654, including engine friction, which efficiency, however, is somewhat doubtful, the discharge having been measured by a water meter, and is probably somewhat nearer 60 per cent. On the other hand, Messrs. Gwynne's pumps at the Groote Ypolder (Holland) drainage showed a mean efficiency of ·656, and in these the vanes are of the Appold type. In this case the discharge was measured by a weir, and the writer cannot help expressing

the opinion that all measurements of water, other than by a tank, in which the actual volume can be exactly calculated, are somewhat open to doubt.

In a ventilating fan, however, high manometric power is desirable, and Rankine or Rateau vanes are preferable, but for a pump the Rateau vane is unsuitable, and for the following reasons :—In the case of a pump it has already been shown that

$$c_1^2 + pc_1Q + qH + rQ^2 = 0 \quad . \quad . \quad . \quad (14)$$

and this is represented by one branch of an hyperbola (Fig. 4, Plate VI.) if H is constant, the abscissæ being values of c_1 and the ordinates values of Q. Now, when a pump is started, the value of c_1 must be near $\sqrt{2gH}$ before discharge commences; the speed may then be reduced until the discharge is represented by A D, and the peripheral speed by O D; but if the speed be increased the discharge will again increase, and the values of Q on A C will never be obtained; it can be shown that with Appold vanes the values of c_1 and Q for maximum efficiency lie on the part A B of the curve, and in general to the right of B; with Rankine vanes, since the efficiency is greatest when the peripheral speed is least, A represents the values of c_1 and Q for maximum efficiency; but with the Rateau vane the less the value of Q the smaller will w_1 be, because

$$w_1 = c_1 + u_1 \cot \varphi,$$

where φ is the acute angle made by the relative direction of discharge with the tangent to the fan, so that for any value of c_1 the hydraulic efficiency will be higher for the lower of the two possible values of Q. Consequently the point of the curve representing c_1 and Q at maximum efficiency will lie on A C, and the pump can never give this value of Q.

Although no experiments have been made relating to the losses of head in air, due to sudden changes of direction and velocity, it is exceedingly probable that they are of the same form as those given in equations (1) to (9*d*), and in support of this will be found below the equations of several ventilators, with tables comparing the calculated values of H with those obtained by experiment, so that it may be assumed that the equation of every fan is of the form :—

$$c_1^2 + pc_1Q + qH + rQ^2 = 0 \quad . \quad . \quad . \quad (14)$$

where r and q are always negative. Now, assuming the above, in the case of a fan $H \propto Q^2$, if the passages through which the air passes are unchanged, and consequently

$$c_1^2 + pc_1Q + sQ^2 = 0 \quad . \quad . \quad . \quad (14a)$$

is the equation of the fan for a given orifice. The fan can therefore

work at any orifice, whatever form of vanes may be used, and if they are of the Rateau form a high manometric power may be obtained; the above equation is represented by two straight lines passing through the origin, one above the axis of x and one below; and as the latter gives negative values of Q it need not be considered. Whether or not the losses of energy in a fan are of the form given in (1) to (9*d*) we may certainly assume that maximum efficiency may be obtained by avoiding sudden changes of direction and velocity, and, as far as possible, curvature of path and surface friction, and discharging the air with as low a velocity as possible. As the Rateau fan (designed by Prof. Rateau of the School of Mines, St. Etienne) fulfils these conditions, it is introduced here as an illustration of the complete theory of the subject.

One of these fans is illustrated in Figs. 5, 5*a* (Plate VI.). The fan centre consists of a cast iron wheel A, upon which the vanes are fixed. A is formed by the revolution of the arc of a circle about the axis. At the eye it is conical, and at the periphery it is normal to the axis. In small fans the vanes are placed in the mould when A is cast, and in larger sizes they are held to it by angle irons. The number of vanes is 20 to 24 for small fans, and 24 to 30 for larger ones. The edge *c d* of the vanes is as close to the casing B B as possible; and *c d* is calculated so that the relative velocity of the air between the vanes either remains constant or increases slightly from inflow to outflow. The fan centre is fixed to the end of the shaft, and the air is guided at inflow by the conical end *a f a*, and also by the conical or bell mouthed inlet Q Q, and experiment shows that, at inflow, the velocity of the air is nearly uniform over the whole section. The casing contains diffuser and volute, which ends in a conical chimney. The diffuser increases slightly in width from inflow to outflow, and is spiral in form instead of circular, its height increasing in proportion to the angle measured from the radius through C to the bottom of the chimney. This necessitates a volute whose cross section σ increases according to the law:—

$$\sigma = \left(x \frac{\theta}{360} + y \frac{\theta^2}{360^2}\right) \frac{Q}{v_1} \quad . \quad . \quad . \quad (15)$$

where v_1 is the velocity at the commencement of the spiral and x and y are suitable constants, Q is the number of cubic feet per second and θ is the angle in degrees measured from the radius through C. The kinetic energy of the air is thus reduced and its pressure is increased. It is found that the above arrangement gives better results than a circular diffuser and a volute, which increases in section in proportion to the angle θ. The necessity of a volute whose section is calculated by equa-

tion (15) is supposed to be due by some to the fact that contraction takes place in the volute, but, according to Prof. Rateau, it is due to the fact that the velocity of the air is reduced in the volute by the curvature of its path. To quote from his paper, "Considerations sur les Turbo Machines":—

Since the trajectories of the fluid are curved it follows that the static pressure is greater on the convex side, but with increase of static pressure there is also an increase of static energy and a diminution of dynamic energy causing the reduction of velocity. This reduction in velocity is an excellent thing, because the volute converts the kinetic energy into pressure energy, the conical chimney is shorter, and the losses by friction are less.

These fans receive the air on one side as a rule; this makes the installation easier, and avoids sharp corners before the eye of the pump. However, the wheel is not then completely balanced, and means have to be taken, such as a collar bearing, to prevent end motion. This lateral pressure is, however, only very small, because care is taken by means of the casing to isolate the wheel from the atmospheric pressure. In consequence the re-entry of air at space which exists between the periphery of the fan and the internal circumference of the diffuser is prevented, and the pressure behind the fan is lowered much below that of the atmosphere, so that the wheel is only very slightly pressed towards the suction side, and this is sometimes completely balanced by the centrifugal force of the air on the curved cast iron surface of the fan. The theory of the construction of the vanes is somewhat complicated and mathematical, and is therefore given in the Appendix. They are made of wrought iron, and stamped in a mould. A vane of this form has the following advantages: —It is very rigid in consequence of its curvature in every direction, and the trajectory of every particle of fluid has an almost constant curvature, which is of great importance in lessening eddies. Table I. gives the proportions of these fans.

Experiments.

Very few experiments on centrifugal pumps are published in detail, and very few papers have been written dealing thoroughly with the subject. In the minutes of the *Proceedings of the Institution of Civil Engineers*, vol. xlvii., will be found some very carefully made experiments on a centrifugal pump by the Hon. C. A. Parsons. These are given in Table III. (see Fig. 10, Plate V.) and confirm the theory given in this paper. After running the pump at various orifices an experiment was made to find the work required to revolve the pump at 410 revolutions, the mean of the number during the experiments

TABLE I.—PROPORTIONS OF RATEAU FANS.
(The radius of the fan is designated by R.)

		Types.		
		A For Large Volumes and Small Pressures. (See Fig. 12, Plate V.)	B For Moderate Volumes and Pressures.	C For Small Volumes and High Pressures.
Suction Orifice—				
External radius	r	·6 R	·5 R	·40 R
Radius of cone	ρ	·25 R	·25 R	·25 R
Area of suction orifice ...	O	R^2	·6 R^2	·35 R^2
Vanes—				
Initial inclination at the circumference of the suction orifice	β	45 degs.	45 degs.	45 degs.
Final inclination at the circumference of the fan	α	45 degs.	60 degs.	60 degs.
Depth of vane { at inflow	a	·40 R	·28 R	·19 R
Depth of vane { at outflow	e	·16 R	·08 R	·045 R
Diffuser—				
Width	e'	·175 R	·09 R	·05 R
Depth of the spiral { initial ...	h	·10 R	·10 R	·10 R
Depth of the spiral { final	H	·50 R	·50 R	·50 R
Inclination of one face to another	γ	4 degs. + 3 degs.	4 degs. + 3 degs.	3 degs. + 2 degs.
Approximate length of the spiral*	λ	9·2 R	9·2 R	9·2 R
Volute—				
Formula giving the sections as functions of the arc of the spiral x† ...	s	$\cdot 50\, x\,(1 + \cdot 8\, x)$ O	$\cdot 45\, x\,(1 + x)$ O	$\cdot 40\, x\,(1 + 1\cdot 2\, x)$ O
Chimney—				
Height‡	L	5 to 7 R	5 to 7 R	5 to 7 R
Angle of chimney ...	θ	7 degs.	6 degs.	5 degs.

* The end of the spiral is at a distance R from the point which is on a radius passing through the origin of the spiral.

† x is the ratio of the length of the arc of the spiral from the origin to the point at which the section is to be calculated to the total length of the spiral λ.

x may be calculated as a function of the angle ϖ between two radii passing through the origin of the spiral and the point of the spiral where the section is to be calculated by the following formula:—

$$x = \frac{\varpi}{480}\left(1 + \frac{\varpi}{1960}\right)$$

ϖ being expressed in degrees.

‡ Calculated from the end of the spiral.

TABLE III.—EXPERIMENTS BY MR. PARSONS WITH A CENTRIFUGAL PUMP.
(SEE FIG. 10, PLATE V.)

No. of Experiment.	Gallons per Minute.	Lift in Feet.	Foot-pounds Raised per Minute.	Foot-pounds Indicated per Minute.	Revolutions per Minute.	Efficiency per Cent.	Corrected Efficiency per Cent. η_2.	$\frac{gH}{c_1 w_1}$ η_1.	$\frac{H}{H+L}$ η_3.
1	1,012	14·67	148,461	208,438	392	49·74	58·57	57·5	57·9
4	1,280	14·7	188,160	343,754	398	54·74	62·99	58·7	60·1
6	1,431	14·75	211,073	374,954	400	56·20	63·95	60·0	62·1
8	1,568	14·75	231,280	404,737	403	57·01	64·29	61·2	61·25
10	1,695	14·75	251,987	419,790	405	60·17	67·18	62·1	65·0
11	1,753	14·8	259,450	435,630	406	59·42	66·39	63·25	65·9
12	1,012	17·4	176,088	370,458	424	47·53	54·06	56·2	53·75
15	1,280	17·3	221,440	417,214	428	53·08	59·51	58·7	60·0
17	1,431	17·4	248,994	447,552	431	53·63	61·86	60·0	60·75
19	1,568	17·4	272,832	471,552	433	57·86	63·95	61·2	6·37
21	1,695	17·6	298,310	486,050	435	61·37	67·64	62·6	64·7
22	1 753	17·6	308,528	494,210	436	62·43	68·68	63·5	64·9

while the pump was not discharging; it was found that 45,000 foot-pounds per minute were required, and this was deducted from the work done by the engine, and the work done by the pump being divided by this was called the corrected efficiency. This quantity is, however, more than the hydraulic efficiency, because the work required to drive a pump when not discharging is very much greater than the work expended in overcoming the friction of the fan shaft. As an illustration of this, a Rateau fan required 1·41 horse-power to drive it at zero orifice, and a peripheral velocity of 131 feet per second, while at maximum efficiency it only required 2·33 horse-power, the tip speed being then 133 feet per second. The causes for this are so obvious that it is not necessary to detail them. The real hydraulic efficiency obviously is between this corrected efficiency and the ratio of the work done by the pump to that done by the engine which drove it by a belt. It will also be seen that the calculated efficiencies lie between the latter and Mr. Parsons's corrected efficiencies, and are, therefore, close to the real efficiencies of the pump; the method of calculating these is given in the Appendix. The equation connecting revolutions per minute R, H the head in feet, and G the gallons per minute is

$$R^2 + \cdot 02225\ GR - 9850\ H - \cdot 01285\ G^2 = 0 \quad . \quad (16)$$

which may be readily thrown into the form

$$c_1^2 + pc_1Q + qH + rQ^2 = 0 \quad . \quad . \quad . \quad (14)$$

In Table IV. below will be found a comparison between the actual value of H and that calculated from the above equation.

TABLE IV.—COMPARISON BETWEEN THE RESULTS OF EQUATION 18 AND THE VALUES OBTAINED BY EXPERIMENT.

No. of Experiment.	Actual Head.	Calculated Head.	Difference.
1	14·67	15·1	− ·43
4	14·7	15·05	− ·35
6	14·75	14·86	− ·11
8	14·75	14·71	+ ·04
10	14·75	14·4	+ ·35
11	14·8	14·6	+ ·2
12	17·4	17·85	− ·45
15	17·3	17·66	− ·3
17	17·4	17·45	− ·05
19	17·4	17·35	+ ·05
21	17·6	17·05	+ ·55
22	17·6	17·16	+ ·46

The writer has to thank Messrs. Boyd and Wallis, of the Wallsend Slipway and Engineering Company, for enabling him to carry out some experiments with one of Messrs. Tangye's pumps; his thanks are also

due to Messrs. Coleby, Piercy, and Low for their valuable assistance in carrying out the same. In this pump the diameters of the suction and discharge are 36 inches.

The diameter of fan is 5 feet 6 inches and its internal width at the circumference is $5\frac{3}{4}$ inches. The internal diameter is 3 feet 3 inches and the vanes are radial at the inner circumference and curve back in the arc of a circle until they become tangential at the outer periphery. Two pumps are provided, each driven independently, to pump out the company's dry dock, and there is, in addition, a 10 inch centrifugal pump for dealing with the leakage. On the day of the experiment, special care was taken in closing the gates to minimise the leakage, and it was evident at the end of the experiment, when the head outside the dock was more than 18 feet, that, in comparison with the large volumes pumped, the amount was negligible, amounting to not more than 1 per cent. The suction pipe is 15 feet 6 inches long and 36 inches in diameter and enlarges with a bend to 54 inches diameter at the junction with the discharge pipe of the second pump. The remainder of the discharge pipe is 95 feet in all, 54 inches diameter, with one right angle bend.

Formulæ (10*a*) (10*b*) have already been given for calculating the loss due to friction of pipes and bends, and in this case the total loss of head referred to the velocity v_4 of discharge from the pump was found to be $\cdot 023293 v_4^2$; this, however, including $\frac{u_1^2}{2g}$, the loss due to the radial component of the velocity of discharge from the fan itself. In addition to this there is the frictional loss due to bends and surfaces in the pump itself, which is of the form $F\frac{v_4^2}{2g}$, and in this case F = 3, so that

$$F\frac{v_4^2}{2g} = \cdot 0469\ v_4^2.$$

Adding $\cdot 023293\ v_4^2$ we get $\cdot 070193\ v_4^2$.

The above value of F is chosen as it gives the best agreement between theory and practice in the nineteen cases of Table II. (page 54).

The other two losses are at inflow and outflow; since the vanes are radial, the former is $\frac{c_2^2}{64}$ where c_2 is the velocity of the inner radius of the fan, and the latter is $\frac{(w_1 - v_4)^2}{2g}$. Adding these losses to the head, and dividing the head by the sum we have the hydraulic efficiency, and it will be seen from Table II. that the difference between theory

TABLE II.—TRIAL OF A TANGYE'S CENTRIFUGAL PUMP AT THE WALLSEND SLIPWAY, MARCH 13TH, 1897. (SEE FIG. 11, PLATE VII.)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Fall of water inside dock in feet	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
2. Head outside dock	19 8	19 8	19 8	20 0	20 0	20 0	20 0	19 10	19 10	19 10	19 10	19 10	19 9	19 6	19 3	19 2	19 2	19 0	19 0	18 9
3. Head inside dock at end of interval	19 0	18 0	17 0	16 0	15 0	14 0	13 0	12 0	11 0	10 0	9 0	8 0	7 0	6 0	5 0	4 0	3 0	2 0	1 0	—
4. Boiler pressure	120	113	107½	105	110	110	105	105	105	105	110	110	110	110	110	110	110	110	110	110
5. Interval in minutes	—	7½	7½	7½	7½	7½	8	8¼	8¼	8	9¼	9½	9¾	9¾	10½	10½	10½	10½	10½	10½
6. Mean head	—	1⅛	2⅛	3⅛	4⅛	5½	6½	7 5/12	8⅓	9⅓	10½	11⅓	12·29	13⅓	13⅞	14¾	15·7	16·58	17·5	18·375
7. I.H.P.	—	220·7	239·6	233·25	240·6	248	247·2	253·8	246·75	245·9	259·1	255	255	261·5	255·8	254·5	272·7	271·25	253·25	257·75
8. W.H.P.	—	12·12	21·1	34·1	46·1	53·9	59·75	66·1	72	76	79·25	84·6	89·4	95	91·1	96·75	99·25	102·7	103·2	105·5
9. F.H.P.	—	9·14	10·1	10·15	10·4	11·4	11·4	12·08	11·63	12·3	13·44	13·76	13·76	14·42	14·3	14·56	15·6	16	16	16
10. S.H.P.	—	211·56	229·5	223·1	230·2	236·6	235·8	241·7	235·12	233·6	245·6	241·24	241·24	247·08	241·5	239·94	257·1	255·25	237·5	241·75
11. Hydraulic efficiency, per cent., η	—	5·74	9·62	15·27	20·4	22·4	25·3	27·4	30·7	32·5	32·3	35·1	37·1	38·5	37·75	40·4	38·55	40·1	43·6	43·5
12. Calculated efficiency, per cent., ηc	—	6·15	9·7	14·15	17·9	21·1	24·9	27·4	30·1	32·9	34·2	36·6	38·5	39·3	40·25	41·8	41·1	42·25	44·4	44·5
13. $\eta - \eta c$	—	− ·41	− 0·8	·57	2·5	1·3	0·4	0	0·6	0·4	−2	− 1·5	− 1·4	− 0·8	− 2·5	− 1·4	− 2·55	− 2·25	− 0·4	− 1
14. Revolutions per minute	—	125·5	136·5	137·5	140·3	144	144	145·9	144·8	147·1	151·1	152	152	154·5	154·1	155	158·7	159·2	157·7	159·7
15. Velocity of discharge from pump	—	12·7	12·7	12·72	12·75	12·2	11·4	11·1	10·75	10·1	9·56	9·3	9·0	9·02	8·17	8·15	7·9	7·71	7·35	7·2
16. Orifice $\frac{Q}{\sqrt{gH}}$ square feet	—	16·25	10·8	8·66	7·5	6·5	5·62	4·8	4·66	4·16	3·73	3·43	3·2	3·11	2·74	2·65	2·481	2·37	2·195	2·09
17. Time	9 45	9 52½	10 0	10 7½	10 15	10 22½	10 30½	10 38¾	10 47	10 55¾	11 5	11 14½	11 24½	11 34	11 44½	11·55	12 5½	12 16	12 26½	12 37
18. Quantity discharged during interval in cubic feet	—	41,209	40,428	40,408	40,383	38,784	38,761	38,738	37,525	37,503	37,480	37,280	37,255	37,234	36,341	36,218	35,095	34,278	32,698	31,900
19. $\frac{gH}{c_1 w_1}$ * × 100	—	9·5	10·9	17·85	21·7	23·7	25·6	27·7	30·6	31·5	30·7	32·3	34·45	35·6	35·8	36·9	36·2	37·8	40·0	39·7

* The angle of relative discharge from the fan is assumed to be at 26° 26′ from a tangent to the periphery of fan, this being the mean angle. The angle varies between 30° and 22° 53′.

and practice is trifling. The efficiency in this set of experiments (see Fig. 11, Plate VII.) is low because the pump was evidently run at orifices much higher than the best, but better results would have been obtained had the vanes not been radial at inflow. These experiments are given in full in Table II. An example of calculating the hydraulic efficiency is given in the Appendix.

The Farcot centrifugal pump, designed and constructed by Mr. Joseph Farcot, of St. Ouen, Seine, is illustrated in Figs. 6, 7, and 8 (Plate VII.), a complete description of which will be found in *Engineering*, vol. xliii., page 93. The vanes are helicoidal, ending radially, and the axis is vertical; in normal working the discharge is 212 cubic feet per second, and the head 10 feet, the number of revolutions per minute being 32, with a peripheral speed of 20·8 feet per second, as the external diameter is 12·466 feet. Experiment gives an efficiency of 65 per cent., and allowing a mechanical efficiency of 90 per cent. for the engine, the hydraulic efficiency will be 72¼ per cent.

The experiment,* however, at which this efficiency was obtained showed a mean speed of 34·4 revolutions, and as the head was 10·3 feet the manometric power was 65·9 per cent. The discharge was measured by a water meter, and it is possible that this somewhat over-estimated the result; it is not, however, stated here that angle of vane and relative discharge from the fan coincide, and although the vanes end radially, it does not follow that manometric power and efficiency are absolutely equal.

The section of the volute and the form of vanes were found by experiment, five different forms having been tried. The firm claims a hydraulic efficiency of 80 per cent., but the writer has noticed that this and other firms are apt to over-estimate the excellence of their machines, and it is probable that an hydraulic efficiency of over 75 per cent. has not yet been attained. The curve of the section of the volute is that formed by a bent spring whose length is varied to form the varying section of the volute. An ingenious moulding machine in which a spring is used has been constructed for sweeping out the body of the pumps. It is claimed that this section is preferable to others, as it entirely does away with eddies in the volute.

In a paper† recently read before the Institution of Civil Engineers will be found ten experiments on a small Rateau fan, the fan centre having a radius of 9·8 inches; part of this is given in Table V. with the values of H in inches calculated from the equation—

* "Notice sur les Nouvelles Pompes Centrifuges, Système," Joseph Farcot. Extrait des *Annales des Pontes et Chaussées*, September, 1888.

† *Proceedings of the Institution of Civil Engineers*, vol. cxii., page 277.

$$c_1^2 + \cdot 0649 c_1 Q - 4440 H - \cdot 00196 Q^2 = 0 \quad . \quad . \quad (17)$$

where c_1 is the peripheral velocity in feet per second, and Q the number of cubic feet of air per minute. As the proportions of this ventilator are the same as those in Table I. (page 51), type A, it is possible to calculate the efficiency represented by the fraction $\frac{gH}{c_1 w_1}$, and these are given in the last column of Table V. (page 57). In the Appendix will be found an example of this calculation: the agreement between theory and practice is possibly owing to a Pitot tube, and not an anemometer, having been used, as it is a well-known fact that an anemometer invariably exaggerates the discharge; the reason probably being that an anemometer gives greater readings for variable currents than when their velocity is constant. All calculations of efficiency from the formula $\frac{gH}{c_1 w_1}$ for a Rateau fan will be found to give lower values than the experimental values in cases where an anemometer has been used, which rather confirms this theory than otherwise, because it implies that w_1 is exaggerated by the anemometer reading. It is possible, however, that the Pitot tube is not the only cause of accuracy.

It will be noticed that there is one discrepancy, namely, in equation (9), the actual being very much less than the calculated efficiency; but since $\frac{c_1 w_1}{g}$ is the work done per lb. of air passing through the fan, and no account is taken of air continually circulating in the casing, the formula $\frac{gH}{c_1 w_1}$ should, as a rule, be slightly greater than the efficiency, and markedly so for small orifices: work has to be done to overcome the friction of air at the back of the fan, and it is also possible that when the discharge is very small that short circuiting at the eye may occur. Curves of efficiency and manometric power are continuous, but the former is zero at zero orifice, and the latter in this case $\frac{1}{2}$, so that although $\frac{gH}{c_1 w_1}$ does not differ much from $\frac{gH}{c_1^2}$ at a small orifice, because w_1 is little different from c_1, the former formula cannot be expected to give the efficiency.

Although the author attaches but little scientific value to the results of experiments made with an anemometer, in Table VI. (page 58) will be found seven experiments on a Rateau fan 13 feet $1\frac{1}{2}$ inches diameter. These are to a certain extent comparable with ordinary fan experiments; as however, anemometers frequently give mechanical efficiencies of over 80

TABLE V.—EXPERIMENTS WITH A RATEAU VENTILATOR, 9·8 INCHES RADIUS.

No. of Experiment.	Static Pressure in Inches of Water.	Dynamic Pressure in Inches of Water.	Quantity Q in Cubic Feet per Minute.	Velocity c_1 of the Circumference of Fan.	*Mechanical Efficiency per Cent. (Dynamic).	Manometric Power per Cent. Calculated from the Dynamic Head.	Orifice $\frac{Q}{\sqrt{gH}}$.	Calculated Static Pressure.	Calculated Dynamic Efficiency.	Difference between Static Pressures, Actual and Calculated.	Difference between Dynamic Efficiencies, Actual and Calculated.
1	$\frac{3}{4}$ vacuum.	$\frac{5}{8}$	3,560	72·6	12·0	26·9	1·57	·61 vacuum	12·0	− ·14	0
2	$\frac{1}{4}$,,	$\frac{13}{16}$	3,536	73·6	17·1	33·6	1·39	$\frac{1}{2}$,,	15·25	0	+ 1·75
3	$\frac{1}{8}$,,	$1\frac{1}{8}$	3,303	76·1	21·3	42·8	1·11	·1745 pressure	20·85	− ·2295	+ ·15
4	$1\frac{1}{8}$ pressure.	$2\frac{1}{8}$	3,395	88·6	33·9	60·4	0·82	1·09 ,,	31·7	+ ·035	+ ·2
5	$2\frac{1}{2}$,,	$3\frac{1}{2}$	3.064	100·7	47·0	77·4	0·58	2·52 ,,	44·0	+ ·02	+ 3·0
6	$3\frac{7}{8}$,,	$4\frac{3}{4}$	2,700	110·8	59·4	87·0	0·43	3·94 ,,	59·8	− ·065	+ ·1
7	$5\frac{5}{8}$,,	6	2,012	127·4	59·9	83·2	0·29	5·625 ,,	54·0	0	+ 5·4
8	$5\frac{3}{4}$,,	$5\frac{7}{8}$	1,510	133·3	60·6	74·4	0·22	5·81 ,,	57·75	− ·006	+ 2·85
9	$5\frac{1}{4}$,,	$5\frac{1}{2}$	773	130·9	49·9	72·3	0·12	5·07 ,,	62·5	+ ·18	− 12·6
10	$3\frac{13}{16}$,,	$3\frac{7}{8}$	0	131·1	0	50·0	0	3·87 ,,	0	− ·058	0

* The work lost by friction has been deducted from the indicated horse-power in making this calculation.

per cent., they must be taken for what they are worth; and this, it may be mentioned, is often the case when the anemometer has been tested in the usual way.

In the *Revue Universelle des Mines*, vol. xx., may be found three experiments with a Rateau ventilator, giving efficiencies of over 80 per cent. The sole licensees and makers of this fan in Great Britain are the Waddle Patent Fan and Engineering Company.

TABLE VI.—EXPERIMENTS ON A RATEAU PATENT FAN, 13 FEET 1½ INCHES IN DIAMETER TO THE EXTREMITIES OF BLADES, AT THE CONSOLIDATION MINES, WESTPHALIA.

No. of Experiment.	Revolutions of Engine.	Revolutions of Fan.	Volume in Cubic Feet per Minute.	Water-gauge.	Horse-power of the Air.	Horse-power of the Engine.	Mechanical Efficiency.	Manometric Power.	Equivalent Orifice.
							Per Cent.	Per Cent.	Sq. Feet.
1	47	157	137,800	4·7	100·9	141	69	90	24·5
2	59	196·6	166,300	6·8	180	245	70	86	24·4
3	25	85	80,500	1·3	15·75	25·43	62	85	27·1
4	40	135	138,600	3·3	68	106·3	64	85·5	29·4
5	47·5	158	163,200	4·5	107	165·6	64·5	84·5	29·6
6	57·5	193	197,100	6·7	196	297·5	65	85	29·3
7	67·5	227	216,400	9·3	298	401·8	67·5	86	27·4

The fan was guaranteed to give 175,000 cubic feet per minute with 6 inch water-gauge on an equivalent orifice of 28 square feet.

In experiments 3 and 7, the reduction of the equivalent orifice was obtained by contracting the airway.

In calculating the horse-power of the air an allowance has been made corresponding to the natural velocity of the air in the airway.

TABLE VII.

No. of Experiment.	c_1 Peripheral Velocity in Metres per Second.	Q in Cubic Metres per Second.	H Depression in Metres. Actual.	H Depression in Metres. Calculated.
1	29·4	35·3	63	62·5
2	29·4	35·0	65	64·2
3	30·4	34·2	74	71·0
4	32·0	32·7	88	89·0
5	31·35	27·6	92	92·5
6	34·1	23·4	113	113·5
7	34·2	16·5	110	108·0
8	32·8	7·8	84	83·4
9	29·2	1·3	44	47·0
10	34·4	18·5	113	112·0

Table VII.* contains the principal figures of ten experiments made with a Rateau fan, 2 metres in diameter. Calculation shows that the equation of this fan is

$$c_1^2 + 2{\cdot}64c_1Q - 1{\cdot}91Q^2 - 19{\cdot}62H = 0 \quad . \quad . \quad (18)$$

* "Considerations sur les Turbo-machines," by Prof. Rateau, page 170.

where c_1 is peripheral velocity in metres per second, Q is in cubic metres per second, and H is the head of air in metres. The accuracy of the equation is shown by the table.

Table VII*a* is taken from curves of manometric power and efficiency of a fan with plane radial blades. The close agreement between the two values, except when the orifice is very small, is additional support to equation (12), for in this case w_1 should not differ much from c_1. The efficiency here is the ratio of the fan horse-power to that applied to the fan shaft.

In the same experiments fan No. VIII. with Appold vanes and spiral casing has an equation connecting the manometric power and equivalent orifice of the form—

$$\frac{1}{\mu} - \cdot 136 \frac{O}{\sqrt{\mu}} - 14\cdot 18\, O^2 - 1\cdot 69 = 0 \quad . \quad . \quad (19)$$

where μ is the manometric power, and O the equivalent orifice in square feet.

TABLE VII*a*.—COMPARISON BETWEEN MANOMETRIC POWERS AND MECHANICAL EFFICIENCIES FOR FAN NO. III., WITH PLANE RADIAL VANES IN MR. BRYAN DONKIN'S EXPERIMENTS, MINUTES OF THE INSTITUTION OF CIVIL ENGINEERS, VOL. CXXII.

Equivalent Orifice. Square Feet.		Manometric Power. Per Cent.		Efficiency. Per Cent.
0·2	...	67·5	...	57·5
0·4	...	61·5	...	63·0
0·6	...	55·0	...	57·5
0·8	...	46·0	...	47·5
1·0	...	38·0	...	40·0
1·2	...	32·5	...	33·5
1·4	...	27·5	...	30·0
1·6	...	24·5	...	26·0

It will be readily seen that this is equation (14) in another form. Table VIII. gives the actual and calculated values of μ from this equation; the differences are trifling.

TABLE VIII.

Equivalent Orifice. Square Feet.		Actual Manometric Power. Per Cent.		Calculated Manometric Power. Per Cent.
0	...	59·0	...	59·0
0·1	...	52·5	...	54·5
0·2	...	43·0	...	43·5
0·3	...	32·0	...	33·1
0·4	...	24·0	...	24·7
0·5	...	19·0	...	18·6
0·8	...	9·5	...	9·0
1·0	...	6·6	...	6·1
1·5	...	3·0	...	2·87

TABLE IX.—FAN NO. VI. MR. BRYAN DONKIN'S EXPERIMENTS.

Equivalent Orifice in Square Feet.		Calculated Manometric Power. Per Cent.		Actual Manometric Power. Per Cent.
0	...	60·0	...	60·0
0·1	...	57·5	...	58·0
0·2	...	54·1	...	54·0
0·3	...	50·0	...	50·0
0·4	...	40·4	...	43·0
0·5	...	36·25	...	36·25
0·8	...	20·7	...	22·0
1·0	...	14·25	...	15·0

The equation to the above fan is—

$$\frac{1}{\mu} + \cdot 192 \frac{O}{\sqrt{\mu}} - 5\cdot 85O^2 - 1\cdot 666 = 0 \quad . \quad . \quad (20)$$

TABLE X.—FAN NO. X. MR. BRYAN DONKIN'S EXPERIMENTS.

Equivalent Orifice in Square Feet.		Calculated Manometric Power. Per Cent.		Actual Manometric Power. Per Cent.
0	...	57·0	...	57·0
0·1	...	63·0	...	60·0
0·2	...	59·8	...	59·8
0·3	...	51·0	...	52·0
0·4	...	41·6	...	41·6
0·5	...	33·0	...	33·0
0·8	...	17·7	...	17·85
1·0	...	12·1	...	16·0
1·5	...	6·34	...	7·5

The equation to the above fan is—

$$\frac{1}{\mu} + 2\cdot 43 \frac{O}{\sqrt{\mu}} - 13\cdot 55O^2 - 1\cdot 755 = 0 \quad . \quad . \quad (21)$$

TABLE XI.—FAN NO. XI. MR. BRYAN DONKIN'S EXPERIMENTS.

Equivalent Orifice in Square Feet.		Calculated Manometric Power. Per Cent.		Actual Manometric Power. Per Cent.
0	...	28·5	...	28·5
0·1*	...	32·8	...	26·0
0·24	...	19·0	...	19·0
0·3	...	14·5	...	15·5
0·4	...	9·47	...	10·5
0·5	...	6·5	...	6·5
0·8	...	2·78	...	2·8
1·0	...	1·8	...	2·0
1·5	...	·08	...	1·0

* The smallest equivalent orifice at which a test was made, except zero orifice, was ·24 square feet.

The equation to the above fan is—

$$\frac{1}{\mu} + 10\cdot 05 \frac{O}{\sqrt{\mu}} - 126\cdot 4O^2 - 3\cdot 51 = 0 \quad . \quad . \quad (22)$$

In conclusion, the proof has been attempted in the above pages of a theory which has already been applied to turbines, and is acknowledged to be accurate, and which also, in the author's opinion, explains the working of centrifugal pumps and fans. In the former, carefully conducted experiments, which are absolutely reliable, are very few in number, while in the latter case, experiments with an anemometer are worthless where calculations are required which depend on absolute accuracy in the discharge of the fan. Mr. Donkin's experiments, already quoted, are the only ones which appear to give accurate results as regards efficiencies, especially as the efficiencies are low. This theory explains the cause of the various forms of curves of manometric power, whose general form is only modified by errors due to the anemometer, and this is a strong argument in its favour. In Mr. Parsons's and the author's experiments on the centrifugal pump, both of which were made with great care and accuracy, theory and practice agree as closely as can be expected when unavoidable experimental errors are taken into consideration.

APPENDIX A.

Proof that $\frac{gH}{c_1 w_1}$ gives the efficiency.

In Rankine's *Applied Mechanics*, sec. 562, page 506, the following proposition is proved :—"The variation in a given time of the angular momentum of a body is equal to the angular impulse producing that variation, and has the same axis." Assuming this, suppose that a particle of weight W passes through a fan, and that on entry its angular momentum is $\frac{W}{g} r_2 w_2$ where r_2 is the inner radius of the fan, and w_2 the tangential velocity; and let $\frac{Wr_1}{g} w_1$ be the angular momentum on leaving the fan, then if T be the twisting moment on the shaft due to this particle alone, and t the time during which it acts. $T.t = \frac{W}{g}(r_1 w_1 - r_2 w_2)$. If ϖ is the angular velocity $T.\varpi.t. = \frac{W}{g}(r_1 \varpi w_1 - r_2 \varpi w_2) = \frac{W}{g}(c_1 w_1 - c_2 w_2)$, but $T.\varpi.t.$ is the work done on the shaft, neglecting, of course, the journal friction, so that if W^1 is the total weight passing through per second,

$$T.\varpi. = \frac{W^1}{g}(c_1 w_1 - c_2 w_2),$$

so that the work done by the fan per pound $= \frac{c_1 w_1 - c_2 w_2}{g}$.

Now, either $w_2 = 0$ at inflow, or the fan produces it indirectly, so that in either case $\frac{c_1 w_1}{g}$ is the work done per pound, and as H is the head the efficiency is $\frac{gH}{c_1 w_1}$.

APPENDIX B.

Experiments upon a centrifugal pump by the Hon. C. A. Parsons; comparison between theoretical and experimental efficiencies.

The dimensions of the pump are given in a paper by Prof. Unwin on the "Theory of the Centrifugal Pump," vol. liii., *Proceedings of the Institution of Civil Engineers.* The external radius of the fan is $r_1 = 9{\cdot}25$ inches $= 2r_2$, the internal radius. The external and internal breadths of

the fan are the same, $= b_1 = b_2 = 5{\cdot}75$ inches. There were eight vanes, and as their thickness is not given they are assumed as $\frac{1}{4}$ inch thick at the ends. The velocity v_4 in the volute is given as $3u_1$ by Prof. Unwin, but as he evidently neglects the vanes this must be modified. Assuming a coefficient of contraction for $\frac{9}{10}$ at discharge from the fan, which is also the custom in the case of radial flow turbines,* we get

$$v_4 = 2{\cdot}35u_1,\ u_2 = 1{\cdot}94u_1.$$

The angle φ made by the vane at the external radius, with a tangent to the fan, is 15 degs., and at the internal radius the corresponding angle is 40 degs., so that

$$\cot\varphi = 3{\cdot}73\ ;\ \cot\theta = 1{\cdot}91.$$

For these angles see Fig. 3 (Plate VI.).

Let G be the number of gallons per minute.

$$u_1 = \frac{G}{60 \times 6{\cdot}25\,(2\pi r_1 b_1 - nb_1t_1 \operatorname{cosec}\varphi)\,K},$$

$$u_2 = \frac{G}{60 \times 6{\cdot}25\,(2\pi r_2 b_2 - nb_2t_2 \operatorname{cosec}\theta)\,K}.$$

Where $n = 8$, the number of vanes,

$K = \frac{9}{10}$,

then $u_1 = G \times {\cdot}001472$.

Taking Experiment 1 as an example, $G = 1012$; $u_1 = 1{\cdot}48$; $v_4 = 3{\cdot}48$; $c_1 = 31{\cdot}55$; $w_1 = c_1 - u_1 \cot\varphi$ and assuming that angle of relative flow and vane coincide.

$$w_1 = 26{\cdot}04.$$

$$\eta_1 = \frac{gH}{c_1w_1} \times 100 = \frac{32{\cdot}2 \times 14{\cdot}67}{31{\cdot}55 \times 26{\cdot}04}.$$

$$= 57{\cdot}5.$$

$$\frac{(w_1 - v_4)^2}{64} = 7{\cdot}8\ ;\ \frac{u_1}{64} = {\cdot}034.$$

Then h_4 is the loss of head at entry into the volute—

$$= \frac{(w_1 - v_4)^2}{64} + \frac{u_1^2}{64} = 7{\cdot}834.$$

$$h_3 = \frac{(c_2 - u_3 \cot\theta)^2}{64} = 2{\cdot}375.$$

The friction of the pump is expressed by the formula $F\frac{v_4^2}{64}$ where the most suitable value of F is 2·5, so that—

$$F\frac{v_4^2}{64} = {\cdot}4725.$$

As the tube by which the head was measured was turned to face the

* *Bodmer's Hydraulic Motors, Turbines, etc.*

current the loss $\frac{v_4^2}{64}$ may be omitted; the efficiencies are in fact dynamic.

Hence if L = total losses—

$$\eta_2 = \frac{H \times 100}{H + L} = \frac{14{\cdot}67 \times 100}{14{\cdot}67 + 10{\cdot}681} = 57{\cdot}9.$$

APPENDIX C.

Method of calculating the hydraulic efficiencies, actual and theoretical, of a Tangye centrifugal pump tested at the Wallsend Slipway, March 13th, 1897.

As an example the 14th ft. is chosen. Experiment gave the following:—I.H.P., 255·8; W.H.P., 91·1; revolutions per minute, 154·1; mean head, 13·875. Quantity of water discharged, 36,341 cubic feet; length of interval, 9¾ minutes.

Velocity of flow 8·17 feet per second at discharge from the pump, the diameter of discharge being 36 inches. The horse-power required to drive the engine alone at 140·5 revolutions was 10·4, and at 160 was 16 horse-power, and at 154·1 it was therefore 14·3 by interpolation.

The horse-power transmitted to the shaft is therefore—

$$\text{I.H.P.} - \text{F.H.P} = \text{S.H.P.} = 241{\cdot}5.$$

$$\text{Pump efficiency} = \frac{91{\cdot}1}{241{\cdot}5} = {\cdot}3775.$$

This differs from the hydraulic efficiency only by the bearing friction, and, neglecting this, the tangential component of the velocity of discharge of the water from the pump $= w_1 = \frac{gH}{c_1\eta}$, where c_1 is the peripheral speed at 154·1 revolutions. As the fan is 5½ feet diameter—

$$c_1 = 44{\cdot}15,$$

$$w_1 = 26{\cdot}6,$$

$$L = \frac{(w_1 - v_4)^2}{64} + \frac{c_2^2}{64} + {\cdot}07v_4^2$$

= Losses of head at discharge from the fan, at inflow to fan, and those caused by friction and bends = 5·3 + 10·7 + 4·66 = 20·66, as the internal diameter of the fan is 3¼ feet and the vanes are radial at inflow. Hence—

$$\frac{H}{H + L} = \eta_c = \frac{13{\cdot}875}{34{\cdot}535} = {\cdot}4025;$$

$$\eta - \eta_c = -{\cdot}025.$$

$$\text{The orifice} = \frac{Q}{\sqrt{gH}} = \frac{\text{cubic feet per sec.}}{\sqrt{gH}} = 2{\cdot}74.$$

APPENDIX D.

Method of calculating the efficiencies of a small Rateau ventilator of 9·8 inches radius of fan from the formula $\frac{gH}{c_1 w_1}$.

The radial component u_1 of the velocity of outflow from a Rateau fan can be calculated from the equation :—

$$u_1 = \frac{Q}{60R^2} \text{ (see Table I., page 51)},$$

where R = radius in feet and Q = number of cubic feet per minute.

$$c_1 = \frac{\pi DN}{60},$$

where D = diameter of fan in feet,
N = revolutions per minute,
$w_1 = c_1 + u_1$,

assuming that the angle of discharge coincides with the angle of vane, and that there is no contraction, both of which, owing to the form of vane, are exceedingly probable.

$$H = \text{dynamic head in inches of water} \times \frac{10{,}000}{144} = \frac{10{,}000h}{144},$$

to reduce the manometer reading in inches to head of air in feet.

$$\therefore \frac{gH}{c_1 w_1} = \frac{32{\cdot}2 \times \frac{10{,}000}{144}h}{c_1(c_1 + u_1)}.$$

Taking Experiment 6 as an example :—

$$Q = 2700. \quad c_1 = 110{\cdot}8.$$
$$\therefore u_1 = 67{\cdot}2. \quad w_1 = 178.$$
$$h = 4{\cdot}75.$$
$$\therefore \frac{gH}{c_1 w_1} = {\cdot}54$$

APPENDIX E.

Construction of the vanes of the Rateau ventilator (Fig. 9, Plate VI.).

K O is the axis of the fan shaft and circles passing through S, P, Q, R have radii equal to the external radius of the fan, while P R is the breadth of the vane at the tip. Take a point B on the circle S and through it draw two arcs B*e*, B C ; the angle made by the arc B*e* with the radius B*x* is 45 degrees for type A and is the angle the vane makes

with the tangent to the outer periphery. The circular arc B C makes an angle C B B with the line B B parallel to the axis such that if u_2 is the intended velocity of the air at normal speed and c_1 is the peripheral speed at the external radius, then

$$\tan \text{CBB} = \frac{c_1}{u_2},$$

and this will ensure that at any point on the arc B*e* the air will meet the edge of the vane when running at normal speed. In tracing out the surface of the vane the arc B*e* moves with B on the arc B C and *e* on a cylindrical surface with *xe* as radius and *xx* as axis; the whole of this surface, however, is not required for the vane. Imagine *adcb* to sweep round the axis K*x* and to cut out a portion; this forms the vane, *ad* being the part near the eye, *bc* that near the periphery, and K*a* forming the cone at the eye.

DISCUSSION.

Mr. G. T. DUNCAN said Mr. Innes had introduced a subject which was obviously of intense interest to the members of the Institution, some of whom, he hoped, would be induced to give the results of their own experience. He had not had an opportunity of checking the indicated horse-powers, and the quantities given by Mr. Innes in his tests of the 36 inch Tangyes centrifugal pumps at the large dock of the Wallsend Slipway and Engineering Company; but from a knowledge of previous results, obtained from similar and smaller pumps of the same make, he thought their accuracy was open to doubt. He might be permitted to mention, that in one dock on the North-East Coast the mean efficiency obtained from Tangyes pumps was over 50 per cent. and the greatest, at the finish a good deal over 60 per cent. Perhaps Mr. Innes would make it clear whether allowance was made for fresh or salt water; also, the friction in suction and delivery pipes, and whether leakage entered into the calculations. The friction of engine represented as 16 horse-power seemed very small. Was it taken by the indicator from engine working light? If so, it would be *more* for the engine loaded. Did Mr. Innes

happen to know whether the engines and pumps were absolutely in line? Any settling of the concrete in the engine house might throw the pumps slightly out of line, and there would then be a considerable increase in friction when the pumps and engines were coupled up. The friction of engine running light appeared only to have been deducted. Might he also enquire whether, when testing, care was taken to extract all the air from the top casing, as, if not, it would make a difference in the amount delivered? It would also be interesting to know how the measurements were taken, as there was always some difficulty in taking accurate levels if there was much movement in the water.

The discussion was adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897-98.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN WEST HARTLEPOOL, ON SATURDAY, JANUARY 15TH, 1898.

VISIT TO THE HARTLEPOOL ENGINE WORKS.

By the kind invitation of Messrs. Thomas Richardson & Sons, the members visited the Hartlepool Engine Works, Hartlepool, on Saturday afternoon, January 15th, 1898.

DESCRIPTION OF WORKS.

One of the most important features in Messrs. Richardson's works, from a technical point of view, is the very complete system of power distribution by means of electric machinery.

Until recently, the power for driving the works was supplied by steam engines situated in the various departments, which received steam from a battery of boilers. The area of steam pipe under pressure was very large, and as the majority of the engines were of old and inefficient design, the cost of driving the works was considerable. To reduce working expenses, Messrs. Richardson decided to drive their shops electrically with the most modern electrical and steam machinery.

The outcome of the very elaborate investigations undertaken by the management, in conjunction with Messrs. D. Selby Bigge & Co., of Newcastle-upon-Tyne, is the excellent plant seen by the members on the occasion of their visit to Hartlepool.

Steam is raised in two single-ended marine type boilers, 15 feet by 10 feet, built for a working pressure of 160 lbs. per square inch. The products of combustion are carried underneath the bottom of the boilers before being discharged into the smoke stack.

The main driving engines are two pairs of horizontal compound Corliss surface-condensing engines (400 millimetres by 690 millimetres by 850 millimetres stroke) running at a speed of 125 revolutions per minute, and designed to indicate 450 indicated horse-power.

The feed, air, and circulating pumps are located in a culvert below the floor of the engine room, and are driven off the low pressure crank disk. The air pumps are of Edwards pattern and have proved eminently satisfactory, running perfectly noiseless at the above speed.

Each of these pairs of engines is combined with a three-phase electric generator, which is capable of absorbing the full power of the engines. The rotating part of these machines consists of the flywheel of the engines, on the circumference of which are fixed the poles of the field magnet system. The winding of these poles consists of a spiral of copper strip, wound up on edge, the several convolutions of strip being insulated from the neighbouring turns by layers of varnished paper. This rotating field magnet revolves within the fixed armature. The laminated iron core of the armature is securely held in a cast iron frame, the whole being divided into two parts for convenience in handling. This ring-shaped armature is supported in position on two star-shaped cast iron frames, which in turn are carried centrally on trunnion rings bolted to the frame of the engines. The armature when in position is thus like a wheel, capable of being rotated round these trunnion rings. The turning moment exercised on the armature by the rotating field magnet when the machine is doing work is taken up on small bed-plates on the ground level at the outer circumference of the armature. These bed-plates are so arranged that, on loosening the tightening screws, part of the bed-plate can be slipped out of its place, which allows the armature to be rotated, there being then sufficient clearance for the screws and their bosses to pass through the embrace of these bed-plates. The advantages claimed for this mode of construction are, firstly, the possibility of carrying the armature absolutely centrally with regard to the rotating part, and, secondly, that it allows easy access to any part of the armature for cleaning or possible repair, without making the pit in which the armature is situated so large as would otherwise be required.

In addition to these two compound engines, a single cylinder engine (400 millimetres by 850 millimetres stroke), surface condensing at 125 revolutions, is situated in the adjoining room, and supplies power to a series of belt-driven continuous-current dynamos. These machines have been in use for many years, and were retained as they were still efficient, and the arc lamps in use were not suitable for alternate current circuits.

A three-phase generator capable of absorbing 120 brake horse-power is also driven by belt from this engine. This machine is used during periods of light loads, such as light night shifts, but can also be used in conjunction with the large machines if desired. The three-multiphase generators are controlled from a massive switchboard of white marble, which contains the necessary measuring instruments, and switches for these machines, and also for twelve motor circuits going to different departments of the works. All the circuits are provided with three-pole fuses which are fixed on slate panels at the back of the board, which is open to the adjoining room.

The motor plant consists at present of four motors of 65 brake horse-power, one of 55 brake horse-power, one of 45 brake horse-power, three of 25 horse-power, one of 20 horse-power, one 15 horse-power, and one 10 horse-power. Of these the large motors are used in the engine and boiler shops, while the smaller sized machines are used for pattern shop, small tool shops, foundry and sheer legs shops. The number and position of the different motors in the shops was not determined by consideration of maximum efficiency, the engines having been for the most part simply replaced by motors.

As much of the shafting in the shops had to be rearranged, it was thought desirable to subdivide this gradually, as experience shows to be most economical. In spite of the fact that a large amount of steam pipe is still in use supplying engines not yet replaced by motors, a very marked saving of coal, amounting to approximately 35 per cent. has been effected, and Messrs. Richardson expect to reduce their coal bill for factory driving by fully 50 per cent.

Speaking generally, the noticeable feature of the whole plant is the extreme simplicity of the electrical machinery. The armatures of the generators are fixed and the rotating part is of such a nature that a breakdown is practically impossible. The motors are of very compact design, taking up a minimum of room, which is often a desideratum in a crowded shop.

Messrs. Richardson have recently added an electrical manufacturing department to their already extensive marine business, and with a view of keeping well ahead in electrical matters, are working in conjunction with Messrs. Brown, Boveri, & Co., of Baden, who have a world-wide reputation as electrical power engineers. Messrs. Richardson are also licensees of the Tesla polyphase patents, and, although having only recently started as electrical engineers have over 3,000 horse-power of polyphase electrical machinery at work and on order for driving and

lighting purposes throughout the United Kingdom. The firm also supply continuous current machinery, but the extreme simplicity of their polyphase system for driving purposes is so apparent that the multiphase machines are being made the leading feature in their electrical business.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897–98.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE THEATRE, TECHNICAL COLLEGE, WEST HARTLEPOOL, ON SATURDAY EVENING, JANUARY 15TH, 1898.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on December 6th, 1897, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. R. Fothergill and H. E. J. Camps to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Coull, Alex. B., Consulting Engineer, Baltic Chambers, Newcastle-upon-Tyne.
Field, Arthur M. C., Electrical Engineer, 110, Sandyford Road, Newcastle-upon-Tyne.
Hartley, W. A., Mechanical Engineer, St. George's Square, Sunderland.
Hayashi, Kazuo, Engineer, 7, Warrington Road, Newcastle-upon-Tyne.
Malin, Reginald P. H., Mechanical Engineer, 183, Hugh Gardens, New Benwell, Newcastle-upon-Tyne.
Matsuda, Mantaro, Engineer, 7, Warrington Road, Newcastle-upon-Tyne.
Ross, Charles, Engineer, c/o Messrs. Smith's Dock Co., Ltd., North Shields.
Walker, Chas. J., Mechanical Engineer, Elswick Works, Newcastle-upon-Tyne.

GRADUATES TO MEMBERS.

Fraser, John Holt, Engineer, 34, Balliol Road, Bootle, Liverpool.
Wyand, Frederick W., Electrical Engineer, 13, Eldon Street, Newcastle-upon-Tyne.

ASSOCIATE.

France, James A., Retired Naval Engineer, St. John Street, Newcastle-upon-Tyne.

GRADUATES.

Andrew, John Davis, Apprentice Engineer, 33, Osborne Road, Newcastle-upon-Tyne.

Edminston, Alex. R., Apprentice Engineer, c/o Mrs. Sheffield, 10, Beaconsfield Square, Hartlepool.

Macartney, Walter C., Mechanical Engineer, Elswick Works, Newcastle-upon-Tyne.

Mitchell, William, Ship Draughtsman, Glen Street, Hebburn-on-Tyne.

Moss, William, Apprentice Engineer, Point Pleasant Hall, Wallsend-on-Tyne.

Todd, Geo. William, Ship Draughtsman, 126, Bede Burn Road, Jarrow-on-Tyne.

Vaughan, Wm. A., Apprentice, The Poplars, Gosforth, Newcastle-upon-Tyne.

Wilson, Edward, Electrical Draughtsman, 13, Ely Street, Gateshead-on-Tyne.

Wotherspoon, William L., Apprentice Engineer, 13, Bellerby Terrace, West Hartlepool.

Mr. A. McGlashan read a paper on the "Water Ballasting of Steamers," which was partly discussed and adjourned.

Mr. H. E. J. Camps read a paper on "Some Considerations in connection with the Transverse Framing of Ships."—The discussion was adjourned.

VISIT TO HARTLEPOOL ENGINE WORKS.

The PRESIDENT proposed a hearty vote of thanks to Sir Thomas Richardson and his partners who had so kindly thrown open their works to them that day and shown them their very interesting electrical installation. He should like to have thought that the business of the meeting on the agenda paper had drawn together this large audience rather than the exhibition which they had had the pleasure of seeing; however, that by the way. He would just ask them to allow him in their name to convey by acclamation a hearty vote of thanks to Sir Thomas Richardson and Mr. Morison for their kindness in showing them their most important electrical installation.

This was agreed to.

Sir THOMAS RICHARDSON, M.P., said that his firm had very great pleasure in throwing open their works to the members of the Institution, as any new departure, such as driving a large engineering establishment by means of electricity, would naturally be of interest to those who were connected with the numerous industrial establishments in the district. The Hartlepool Engine Works had been growing for fifty years; and as a consequence they now covered a large area, and were driven by numerous steam engines, which were extravagant users of steam, and required a large amount of attendant labour. The diminishing profits in marine engineering did not warrant this waste of money, so it was decided, after very careful investigation, to adopt electrical power. The next question was, which was the best system; and in order to decide the matter, he, Mr. D. B. Morison, and Mr. Selby Bigge, had visited all the principal electrically-driven works on the Continent, and they had decided in favour of the three-phase system as being by far the simplest, and the best adapted, in every way, for the driving of works. He had also been very much impressed with the magnitude of the electrical power business of Messrs. Brown, Boveri, & Co., who were certainly the pioneers of the polyphase system on the Continent, and his (Sir Thomas's) firm were now working in conjunction with them in the development of electrical machinery, for all purposes, in this country. He was glad to state that the installation at the Hartlepool Engine Works had already proved itself a great success, as the saving in coal and labour had been fully equal to their expectations. Engineering concerns had suffered for many years with low prices and keen competition, and the only way to keep abreast

of the times was by reducing the cost of the finished article; and there was no doubt whatever that the adoption of electrical power would result in an enormous saving in hundreds of works in this country. He had, as they knew, always had the interests of this Institution at heart, and if the members had benefited by their visit to the Hartlepool Engine Works he was very pleased.

WATER BALLASTING OF STEAMERS.

By ARCHIBALD McGLASHAN.

[Read before the Institution, in West Hartlepool, on January 15th, 1898].

It is not intended in this short paper to trace the origin and development of the systems of water ballasting in vogue in steamers, but rather to enquire how far recent developments in shipbuilding and in the working of steamers affect the subject.

It will be readily granted that these developments have been considerable, and a brief examination of some of them in this connection may be both interesting and useful.

1st.—The general adoption of steel in the construction of the principal parts of vessels in place of iron made a considerable difference in the weight of their hulls—as much as 100 tons in the case of a steamer of 3,000 tons deadweight capacity, and in larger vessels somewhat in proportion.

2nd.—The fuller form of bottom and bilge now generally adopted in building cargo vessels reduces their draught of water in the light condition compared with what it would be had the leaner form customary a few years ago been retained. And the substituting of flat plate keels in place of vertical bar keels has the same effect.

3rd.—The proportion of beam to draught of water has increased considerably of late. If two vessels of similar deadweight capacity, but one having, say, 4 feet more beam and about 2 feet less load draught than the other, be compared, the wider vessel will draw from 6 to 9 inches less water in the light condition than the other; and the proportion of beam to draught in cargo steamers has in many cases increased to a greater extent than is indicated by this comparison.

4th.—The increased size of modern cargo steamers also tends in the direction of their having, when unladen, less draught in proportion to their dimensions than that of older cargo vessels, which were mostly of smaller size. Many of the fittings and part of the outfit have not increased in proportion to the size of ship. The square rig has disappeared in most cases, and the masts and spars have been reduced in size, while the dimensions of vessels have been increased. There is conse-

quently less weight in vessels on that account than formerly. Deck gear and spare gear are also less now in proportion to the size of ship, and in many cases fewer decks are fitted than was customary a few years ago.

Then, as is well known, the weight of machinery does not increase in proportion to the deadweight capacity of cargo steamers. A 9 knot boat, carrying 3,000 tons deadweight, would have propelling machinery capable of developing about 950 indicated horse-power, but usually working at about 780 indicated horse-power, and weighing about 240 tons under steam; while a 9 knot boat carrying 6,000 tons would have machinery of about 1,400 indicated horse-power, usually working at about 1,140 indicated horse-power, and weighing about 340 tons.

If double the deadweight required double the weight of machinery, the 6,000 ton boat would have about 480 tons of it. The actual weight, however, being about 140 tons less than that, gives the larger ship proportionately less immersion, when unladen, than the smaller one.

It follows also from the foregoing that the bunker coal required is proportionately less in the case of the larger vessel. If the 3,000 ton boat referred to requires, say, 510 tons of coal for 40 days' steaming, the 6,000 tonner would require about 690 tons. But had the consumption increased in proportion to the deadweight capacity it would have been about 1,020 tons in the larger ship. As it is really 330 tons less when commencing the passage in ballast, or about 165 tons less on arrival at the loading port, the immersion of the larger ship is affected correspondingly.

5th.—Independently of changes in the hull and equipment, there are considerable developments in the machinery of vessels compared with former practice, resulting in less weight under steam for a given power of engine, and in much less consumption of coal per indicated horse-power. A vessel may start on a passage in ballast with, say, 750 tons of bunker coal, sufficient with the newest types of machinery to take her to a loading port and back. With the older type of machinery 950 tons would have been required. The newer type has about 200 tons less coal when starting on the passage, or about 100 tons less on arrival at the loading port, and the draught of water of the ship is less accordingly.

The developments which have been enumerated tend to accomplish what shipowners desire. Taken in the gross they tend among other things:—1st. To reduce the cost of ships per ton of deadweight capacity. 2nd. To reduce the draught of water on which ships may carry a given deadweight. 3rd. To reduce the consumption of fuel required to carry a given deadweight at a given speed.

It is quite natural that developments which bring about such results should be welcomed.

They, however, bring about an important reduction in the light draught of a vessel under steam, which requires correspondingly increased ballast, or other weight, to be put on board, so as to give sufficient immersion to enable passages to be made in ballast satisfactorily.

Owing to changes in trade, vessels have now to make long passages in ballast more frequently than was formerly the case. We may, therefore, enquire how far the new conditions are met in the provision made for water ballasting.

The main purpose of ballast in steamers is to increase their draught of water, so as to make them manageable in rough seas, and to immerse the propeller sufficiently to enable it to do its work in a reasonably efficient manner.

In the case of deep and comparatively narrow steamers ballast is sometimes required to ensure stability either when they are without cargo, or when loaded with bulky cargo, such as timber, which stows high. In such vessels the most suitable position in which to carry ballast is in the bottom. But steamers as now built have usually plenty of beam to ensure stability, and it is not advantageous in them to carry in the bottom all the *additional* ballast which they require. Doing so would increase the metacentric height, which in such vessels is already considerable, and make them less sea-kindly in ballast.

An instance will show that in practice it is found advantageous not only to carry more water ballast in ordinary cargo steamers but also to carry it at some considerable height above the bottom. The captain of a steamer of 4,000 tons deadweight capacity reported, three years ago, that when in the coal trade on the west coast of America for some time he had to make the return trips to the coal port in ballast and frequently found it very difficult to do so. In order to improve the conditions of the ship in ballast, for rough weather, he got large wooden tanks constructed on the quarter deck, capable of holding about 130 tons of water. The tanks leaked a good deal but were easily replenished through the wash deck pipe. The weight of water contained in these tanks so improved the conditions of the ship in ballast that she made her return trips with more regularity and less discomfort to those on board. Captains of vessels frequently put 100 tons, or more, of loose ballast on deck, and experience a considerable improvement in the vessel's behaviour on that account.

A brief reference may here be made to the systems of water ballast tanks most commonly in vogue without entering into details which are already well known.

1st.—Double bottom tanks are fitted to most cargo steamers built now, either on the McIntyre system, shown in Figs. 1 and 4 (Plate VIII.), or, and more frequently, on the cellular system, shown in Figs. 3 and 5 (Plate VIII.). In either system the inner bottom may be carried continuously throughout the ship, but in many cases the tanks are fitted as shown in the plates, being omitted under the machinery, or at least under the boilers, for fear of corrosion being accelerated by heat in the tanks if fitted there. Other modifications of the double bottom are sometimes made to suit special circumstances.

2nd.—After peak tanks are usually constructed in steamers, and are very efficient for trimming a vessel by the stern. They are frequently, as shown in Fig. 5 (Plate VIII.), and sometimes carried higher as in Fig. 4 (Plate VIII).

3rd.—Fore peak tanks, shown in Fig. 4 (Plate VIII.), are sometimes fitted, but they do not seem to be much required in ordinary steamers.

4th.—Deep tanks are sometimes formed in the holds of vessels by making a small compartment available either for water ballast, or cargo. They may be fitted either over a double bottom, as shown in Fig. 5 (Plate VIII.), or down to the bottom of the vessel, as shown in Fig. 6 (Plate VIII.). Where the engines are placed further aft than usual the deep tank may be placed forward of the engine room, instead of abaft, as shown in the illustrations. For various reasons, deep tanks do not find much favour. They are usually too confined to work certain cargoes easily in and out of them; and in order to ensure tightness, the hatch openings in them have to be kept somewhat small; then, unless they are kept quite full of water, when used for ballast they are troublesome, because the water set in motion by the rolling of the ship strikes with great force against the bulkheads and decks, and strains them.

5th.—There is also a system by which ballast tanks are constructed on deck; but the writer has had no experience to enable him to speak of the merits of this system.

There are other methods which have either been proposed or adopted, one of which—

6th.—Side tanks may now be described; they are illustrated in Figs. 7, 8, and 9 (Plate IX.), and have the following advantages, viz.:—

(1) They provide capacity for additional water ballast, which we have seen to be necessary in modern cargo steamers, and carry it at such a

height in the vessel as to make her easy in a sea-way; the propeller is consequently further immersed, and the excessive straining of machinery due to "racing" is minimised. This is important, as many breakdowns of machinery are attributable to the straining caused by "racing." In some cases breakdowns occur to the machinery of ships in ballast in rough weather; but fractures may occur, in such circumstances, without being observed, and afterwards develop so as to cause the breaking of a shaft when least expected.

(2) It is reasonable to assume that side tanks will increase the safety of a ship. The shell of an ordinary vessel may easily be injured to such an extent as to leak, and cause damage to cargo; but the side tank plating, where fitted, might remain intact in the case of injury to the shell, and prevent water reaching the cargo, and in some cases it might save the ship from sinking. Double bottoms have often proved efficient in this way, and in some instances have failed only because the injury to the bottom extended beyond the margin of the inner bottom, and so enabled water to enter the holds. This, however, the side tanks would in some cases prevent, and is a feature worthy of attention of those most interested in the safety of life and property.

(3) While the measurement capacity for bale goods is reduced to the extent that the side tanks are deeper than ordinary deep framing, the tonnage of the ship (on which dues are paid) is also reduced to the same extent, and the space available for the stowage of cargo is not interfered with by 'tween decks, projecting stringers, hold beams, gussets, and such like parts as are usual in ordinary vessels, and interfere a good deal with stowage. The hold space is, therefore, rendered more valuable in the way of the side tanks.

The deadweight capacity in many cases will not be reduced by side tanks being fitted, as these give the necessary strength, which in other vessels is usually obtained by fitting 'tween decks, hold stringers, beams, webs, or deep framing and such like, already referred to, and the weight of material in the parts which are dispensed with is about equal, in large vessels, to that required in the construction of the side tanks.

In order not to unduly lengthen this paper a table (page 83) is appended giving particulars of 8 steamers, with the object of showing how newer vessels compare with older ones in displacement and draught of water when the ballast tanks are filled and coals on board for a 20 days' run.

Steamers A, B, C, D, E, and F are representative of a large number of cargo steamers built and at work. The owner of steamer A made it a

rule, from the first, to put about 200 tons of rubbish ballast into her, when cargo was not obtainable, before sending her across the Atlantic in winter. Steamer B was built to do part of the Atlantic trade of her owners when they had cargoes to carry out as well as home.

Steamer C proved an admirable ship in ballast, and in the table she is taken as a standard by which the others are compared, both as to displacement and mean draught of water in the ballasted condition.

At line 19 in the table the displacement of steamer C, in the ballast condition, is found to be ·521 of the load displacement, and at line 20 the draught of water in the same condition is ·589 of the load draught. The lines following give displacement and draught by these factors for each vessel.

Lines 25 and 26 show the deficiency in displacement and draught of each ship in the ballast condition when compared with steamer C, or how much additional ballast would be required in each to bring them to the standard of that steamer, either on the basis of displacement or draught of water. It will be found at line 25, that all the vessels, excepting G, require more ballast to give them the same percentage of load displacement as steamer C. Steamer G has, in consequence of her side tanks, an excess of 180 tons displacement, equal to 5¼ inches draught.

Line 26 shows that all the vessels, including G, are deficient in draught, and how much additional ballast would be required in each to put them on an equality with steamer C. But steamer G, even with a flat keel, is only 3¼ inches deficient in draught, compared with steamer C, which deficiency 106 tons more ballast would overcome. As she has, however, an excess of 180 tons on the displacement basis she may be taken, on the whole, as equal to steamer C in the ballasted condition.

The writer does not contend that ship C should be taken as a standard by which to compare the ballasted conditions of other vessels; nor does he wish it to be understood that comparison by displacement, or by draught, or by both together, would be an unfailing guide to securing the best ballasted conditions of steamers. Other elements, too numerous to be dealt with in one short paper, have a modifying effect. Weight and immersion of ship are, however, main elements in dealing with the subject, and it is to these that attention is specially drawn in the paper.

In conclusion, the writer has to acknowledge his indebtedness to the directors of Messrs. Wm. Gray & Co., Limited, West Hartlepool, for their ready permission to use the data required in preparing the paper.

TABLE OF REPRESENTATIVE CARGO STEAMERS OF DIFFERENT YEARS AND SIZES COMPARED AS TO DISPLACEMENT AND DRAUGHT OF WATER IN BALLAST, STEAMER C BEING TAKEN AS A STANDARD FOR COMPARISON.

1. Ship	A.	B.	C.	D.	E.	F.	G.	H.
2. When built	1883	1883	1883	1889	1892	1897	Building by W. Gray & Co.	Like G but without side tanks.
3. Length between perpendiculars	257′ 6″	285′ 0″	330′ 0″	300′ 0″	330′ 0″	325′ 0″	338′ 0″	338′ 0″
4. Breadth, extreme	35′ 6″	36′ 0″	42′ 0″	41′ 6″	43 0″	47′ 0″	51′ 0″	51′ 0″
5. Depth, moulded	20′ 1½″	25′ 3″	28′ 5″	23′ 0½″	24′ 4½″	24′ 10″	26′ 11″	21′ 11″
6. Depth of keel	0′ 9″	0′ 9½″	0′ 10″	0′ 10″	0′ 11″	Flat plate say 1½″	Flat plate say 1¾″	Flat plate say 1¾″
7. Type of ship	Well-deck	3-deck rule	Spar-deck	Long bridge well-deck	Partial awning-deck	Semi 3-deck	3-deck rule and side tanks	3-deck rule
8. Material built of	Iron	Iron	Iron	Steel	Steel	Steel	Steel	Steel
9. Engines, cylinders	32″ & 60″ / 39″	37″ & 68″ / 42″	43″ & 80″ / 54″	23″, 36½″, 62″ / 39″	24″, 38″, 64″ / 42″	24″, 38″, 64″ / 42″	25½″, 40½″, 67″ / 45″	25½″, 40½″, 67″ / 45″
10. Deadweight capacity, tons	2,340	3,110	4,136	4,065	5,073	5,080	6,139	6,139
11. Block coefficient of load displacement	·740	·743	·720	·767	·800	·798	·799	·799
12. Load displacement, tons	3,550	4,660	6,396	5,695	7,143	7,160	8,779	8,779
13. Load draught	19′ 1¼″	22′ 2″	23′ 3″	21′ 8½″	22′ 11¼″	20′ 8″	22′ 5¼″	22′ 5¼″
14. Weight of ship ready for sea, tons	1,210	1,550	2,260	1,630	2,070	2,080	2,640	2,640
15. Water ballast capacity, tons	316	359	573	624	763	784	1,714	984
16. Bunker coal for 20 days' steaming, tons	260	340	500	300	320	320	400	400
17. Water ballasted and coaled for 20 days, displacement, tons	1,786	2,249	3,333	2,554	3,153	3,184	4,754	4,024
18. Water ballasted and coaled for 20 days, mean draught	10′ 11½″	12′ 4¾″	13′ 8½″	11′ 2″	11′ 6″	10′ 1″	12′ 11¼″	11′ 2¼″
19. Displacement, water ballasted and coaled for 20 days = load displacement ×	·503	·482	·521	·448	·441	·444	·541	·458
20. Mean draught, water ballasted and coaled for 20 days = load draught ×	·574	·564	·589	·514	·501	·488	·576	·499
21. Displacement = ·521 of load displacement =	1,849	2,428	3,333	2,967	3,721	3,730	4,574	4,574
22. Displacement = ·521 of load displacement gives mean draught	11′ 3⅜″	13′ 1⅝″	13′ 8½″	12′ 7⅛″	13′ 2″	11′ 6⅝″	12′ 6″	12′ 6″
23. Draught = ·589 of load draught =	11′ 3″	13′ 0½″	13′ 8½″	12′ 9½″	13′ 6″	12′ 2″	13′ 2½″	13′ 2½″
24. Draught = ·589 of load draught gives displacement, tons	1,840	2,403	3,333	3,023	3,838	3,961	4,860	4,860
25. Deficiency by displacement basis (line 21) tons	63	179	—	413	568	546	+ 180	550
„ Deficiency by displacement basis (line 22)	0′ 3⅜″	0′ 8⅞″	—	1′ 5⅛″	1′ 8″	1′ 5⅝″	+ 0′ 5¼″	1′ 3¾″
26. Deficiency by draught basis (line 23)	0′ 3½″	0′ 7¾″	—	1′ 7½″	2′ 0″	2′ 1″	0′ 3¼″	2′ 0¼″
„ Deficiency by draught basis (line 24) tons	54	154	—	469	685	777	106	836

It has been suggested that an explanation of the table might be made.

If they looked along line 25 they would see under A, 63, which is the number of tons additional ballast that would be required to place that steamer on an equality with steamer C upon the basis of percentage of load displacement. The next steamer would require 179 tons ballast to put her on an equality with steamer C, which has been chosen as the standard. Still continuing line 25, and under D, they found that 413 tons more were required; and so on along the table till they came to G, which had an excess of 180 tons. The same ship, if built without side tanks, as shown under F, would have a deficiency of 550 tons.

In line 26 the deficiency of ballast is shown on the basis of draught of water. Members might ask why draught of water was introduced as a basis of comparison. With most ships the propeller goes down to within a given distance from the bottom of keel, whether the keel is of bar or flat plate form. The first ship A requires, on this basis, an additional 54 tons of ballast. The second, B, 154 tons. D, a steel ship, with triple engines, requires 469 tons. E requires 685 tons; while the next, F, having a flat plate keel, requires 777 tons to put her down to the same proportionate draught as steamer C. Steamer G, again, with side tanks containing 730 tons of additional ballast, would require a further 106 tons to put her down to the same proportionate draught as steamer C; but seeing that she has an excess of 180 tons when compared by the displacement basis, if we take the mean of these she seems to compare very favourably with C. As shown under F there would be a deficiency of 836 tons of ballast.

DISCUSSION.

Mr. J. R. Fothergill, in opening the discussion, said the subject of the paper was one of great importance—a subject which at the present time caused considerable uneasiness in the minds of all those actively interested in modern steamers. He believed everybody conversant with the subject must admit steamers were not sufficiently ballasted when proceeding light ship. Referring to the table given at the end of the paper the most unpractical shipowner must realise it was impossible for a steamer, say, as given under heading F, to make headway against a gale. This steamer F carries 5,080 tons deadweight. When light ship in water-ballast and twenty days' coals on board (320 tons) her mean draught was 10 feet 1 inch or about 12 feet by the stern. Suppose this steamer left

Antwerp with only six or eight days' coal on board, the boss of the propeller would be barely covered. He left the members to form their own opinion should this steamer experience a gale rounding Land's End. He might say he had had sea experience, and he certainly should not care to be on board a steamer under such conditions. He was at Barry about the middle of December last and for several days it blew hard. From the Saturday to the Wednesday no less than sixty steamers in ballast arrived at Barry, most of them from three to six days late from the Continent, and one no less than nine days from Liverpool. Owing to the propeller not being sufficiently immersed steamers could not be driven, and unless they could creep into some convenient port the risk to ship and excessive strain upon the machinery must be exceedingly severe. To this cause must be largely attributed the extensive damage to propeller shafts which they now experienced. In a steamer of the dimensions of F, he supposed the propeller would be about 17 feet diameter, and say 6 tons in weight, and the shaft about 12 inches diameter, under ordinary conditions light ship the revolutions would be, say 65, but as soon as the propeller left the water probably 100. The periphery speed of the propeller would be something like 5,300 feet per minute. At this enormous speed the propeller plunged into the water, and in a few seconds the revolutions were so reduced that the engines were nearly stopped, and before the engines could resume the normal condition, the propeller was again out of the water. Under these circumstances the propeller could not drive the vessel, and the strain produced in overcoming the inertia of this high propeller speed must enormously affect the life of the shaft. Steamers were certainly not designed to cross the Atlantic in ballast and bunkers only. If the necessity of the times required steamers to cross the Atlantic without cargo, sufficient ballast should be supplied that the propeller might be sufficiently immersed to propel the vessel. He wished so far as he was able to impress upon shipowners that it was to their interest and advantage to sufficiently ballast their steamers, as there was ample evidence of time saved far more than covered the cost of ballast, to say nothing as to wear and tear and damage to machinery. He fully believed the meeting would endorse the opinion that, particularly in modern steamers, more ballast was a necessity, that being so, he left it to naval architects to say whether Mr. McGlashan's design was one that best fulfilled the conditions required, not only as a question of naval architecture, but with the least possible encroachment on the cargo capacity for additional ballast carried. In conclusion, he desired to thank Mr. McGlashan for his most interesting and able paper.

Mr. ROBERT THOMPSON (Past-President) thought it hardly fair for him to discuss Mr. McGlashan's paper without more careful consideration than he had had the opportunity of giving to it. As far as the subject was concerned, it certainly was one that at the present time was very much to the front; and for that, he thought, their thanks were due to Mr. McGlashan. There was no doubt that a good many of the accidents Mr. Fothergill mentioned as happening to shafts, and also some of the misfortunes happening the fore ends of ships had been caused by insufficient ballast; not so much to ballast out of place, or to the mere fact of crossing the Atlantic, but to the constant hammering on the fore end, when travelling long distances in ballast trim, loosening the riveting. The ballast amidships would certainly immerse the ship bodily, and give her a fair chance to contend against a head sea, such as was encountered in the Atlantic. He would like to ask Mr. McGlashan one question about grain cargoes: What would be the effect of sweating on tank sides, there being no ceiling shown on the plan as was fitted on the tank top of the ship?

Mr. MCGLASHAN—The fitting of ceiling or cargo battens would depend on circumstances. For some trades they would not be required. The ship that Messrs. Gray were building had ceiling on the tank top, but not on the side tanks. The tank sides would be the same as bulkheads which have neither ceiling nor battens fitted on them to prevent sweating.

Mr. THOMPSON said he would like as much information upon the subject as possible. The only thing that struck him, and the only objection he could see to the arrangement was this, the ship's sides were liable to contact with quay walls, and in that way would be more difficult to keep tight than on the bottom of the ship. If a vessel went on a rock, they heard of it, there was no concealing it; but if it bumped against a quay wall, they might not until they found it leaking.

Mr. MCGLASHAN—Would the water leak outwards if the side tanks were full?

Mr. THOMPSON—Both ways.

Mr. MCGLASHAN—Not into cargo, unless the side tank plating was also injured.

Mr. THOMPSON—They discovered that when the cargo was out, because they would not have the tanks full when cargo was in the ship. He was speaking of it as a question of repair.

Mr. McGLASHAN said perhaps he might be allowed to say that there was a valuable feature of the side tank design to which Mr. Thompson's remarks drew attention. It was important to remember that access could be got to the tanks from the deck at any time, and if the outer shell was damaged slightly, water could be pumped out and repairs executed, provided the damage was not too low down, because filling the tank on the opposite side would heel the vessel to raise the damaged side out of the water. That might occur without injury to cargo, and even without requiring it to be discharged.

Mr. THOMPSON was very glad to have that information, and he thought it was one of the successes of this Institution to have firms, such as that of Sir William Gray, allowing detailed information to the writer of this paper, and of Sir Thomas Richardson opening their works to the members, and thus adding to their general information, which was often useful to those giving it. He recognised one of the ships Mr. McGlashan mentioned. His firm was building one without the ballast at the sides, and he would be very willing to compare notes with him.

Mr. G. W. SIVEWRIGHT, in discussing the paper, said it was a mistake to design vessels, more especially cargo boats, for any particular trade, and by making the side tanks as proposed Mr. McGlashan was legislating for a ship to run continually with cargo only one way. The design might be suitable for the deadweight trades, where cubic capacity was of no consequence, but he was quite certain in large steamers the cubic capacity was of as much importance as the deadweight, and if this capacity was reduced the vessel, as a dividend-earning machine, would suffer in consequence. It would have considerably increased the value of the paper if the comparisons had been carried further, and this loss of capacity shown in the tables. Before coming to the meeting he had roughly taken out a ship to show how these were effected in a vessel of the following dimensions :—

Length B.P.	315 ft. 0 in.
Beam extreme	42 ft. 6 in.
Depth moulded	26 ft. 3 in.
Block coefficient	·772
Length of tank over midships	173 feet.
Decrease of bunkers	100 tons.
Decrease of hold capacity	14,056 cubic feet.
Decrease of net tonnage	70 tons.

In his opinion, the loss of capacity and bunkers would not be balanced by the occasional use of side tanks. With large steamers there was no

difficulty in getting well on to 1,000 tons of water ballast, and this had been augmented by carrying ballast in the tunnel. The space taken off in way of side bunkers for side tanks would necessitate the lengthening of the engine and boiler space to make up for this loss. With reference to deep tanks, he could not agree that these were not a satisfactory arrangement. He had just sent a boat to sea with a deep tank holding 1,000 tons of water ballast, with large hatches in the top, making it available for bulky cargo. Many of the large steamers out of London and Liverpool used this type of tank for any extra water ballast they required with satisfactory results. He was quite certain that if both shipbuilders and shipowners would cease building the fuller form of bottom and bilge as mentioned by Mr. McGlashan, and with finer coefficient, these ships would not have the trouble in getting about in ballast which they now have. From his experience, full cargo boats with an extreme block coefficient were quite a mistake for deep sea trading. With reference to the construction of the proposed arrangement of side tanks, he thought there would be considerable increase in the cost of doing the work by practically having two different kinds of framing to contend with, but no doubt this would work itself right in the course of time. In taking a broad view of the design, it appeared to him the side tanks had been introduced more with the idea of doing away with the intermediate deck required by Lloyd's. He hoped the paper would be fully discussed. The practical opinion of many of the members would increase the value of the paper.

Mr. Otto K. Trechmann said he was not a scientific man—only a shipowner. Mr. Sivewright mentioned that they did not talk about cost there. He did not know if that meant original cost, or cost of upkeep; but, looking ahead at this matter as a shipowner, he would like to ask Mr. McGlashan how he got at the inside tanks to paint them, to prevent corrosion, for that, in steel ships, was one of the great factors they had to deal with after the vessel was seven or eight years old?

Mr. McGlashan—There was an open space for getting freely about to examine the parts. The tanks might be entered at any time; that had been looked into, and the general belief was that there would be no difficulty in reference to preserving the tanks.

Mr. Trechmann—What was the width?

Mr. McGlashan—In that particular ship, 2 feet 5 inches.

Mr. J. BLACK remarked that what he had been considering was this: suppose this vessel was coming back from India with, say, a light rice cargo, she would shut out a considerable amount. As Mr. Sivewright had said, a vessel was designed for carrying, not to go light. The Atlantic had been spoken of; but, as had been shown by Mr. Fothergill, he would rather cross the Atlantic in a light ship with, say, 750 tons of bunkers and ballast than make the passage, in bad weather, from Hamburg to Cardiff. He had himself vessels ten days from Hamburg to Cardiff. In crossing the Atlantic, it was well known, they could always make headway some way or other. The question was of more importance in a short trade where the vessel took on board only three or four days' coal. But that was away from the point; he was thinking of a voyage from India, and how much rice this vessel would shut out, and again in the cotton trade, how much would be displaced. These were points they would really have to consider if they were to look for a fair dividend, to say nothing of the first cost of production. Then, of course, there was the other point as regarded the keep up. These tanks would, no doubt, require a vast amount of ventilation. He thought the ventilators would be placed in such a position that they would be very dangerous in a seaway, for he took it that they would be put on the extreme of the beam. These tanks would require a lot of ventilating, or there would be a large amount of sweating going on. With light plating it was very difficult to keep paint on a steel steamer. He did not know what the thickness of this interior would be; but there would be a considerable giving and taking, and it would be a very difficult thing indeed to keep the tanks efficient.

Mr. F. YEOMAN said he was only a shipowner and not a scientific man; but he had read Mr. McGlashan's paper, and like Mr. Fothergill he could not help thinking that Mr. McGlashan was treating upon a most important phase of the mercantile marine of to-day. He traced eight or nine types of cargo steamers they had known during the last fifteen years. Steamer A of 2,350 tons deadweight was built in 1882, and speaking personally he could have wished he had made that vessel instead of steamer C his standard, for he had a distinct recollection of sailors telling him that sometimes when such vessels left ports on the other side of the North Sea, and there came on suddenly a westerly gale, it took them all their time to keep off a lee shore, but in the worst conditions they did it. They had seen all kinds of ships built from year to year, and he thought naval experts would soon be called upon to

tell them "where a 'ship' leaves off and a 'box' begins." From his window he had seen one of the latter with an easterly half gale and strong sea about puzzled to beat out of Hartlepool bay, and as a ship-owner he had not felt flattered that such was the case. Somebody had alluded to going round to Cardiff with few bunkers, and that was no doubt frequently the case. They had, at times, heard from him upon the subject of the inherent weakness of the sailing ship, as such, as compared with steamers, in the matter of life loss, more particularly as touching lee shore, etc., but he was by no means certain that they were not trenching upon a somewhat similar line in the large, light steamer of to-day. He thought the object sought to be brought about by Mr. McGlashan's paper deserved all possible attention. They should treat the ship as a machine, and strive to ensure its being capable of doing its work under every possible condition. The sailor had a perfect right to demand that under all ordinary conditions, and even extraordinary circumstances, his ship should be able to do the work demanded of her, and as to which he ought to be under no undue anxiety. He trusted that the members of the Institution interested would ever keep this phase of seafaring life prominently before them.

Mr. R. Hirst thought they must all agree that Mr. McGlashan had in this paper put before them one of the most important features raised lately in naval architecture. He (Mr. Hirst) was an engineer, and this type of vessel he felt might be one of the greatest advantages their engineers had received for a considerable time. The ship was practically doubled. Mr. Fothergill said a great many shafts were broken, but the tendency of this new design was to considerably stiffen the ship, and there would be less failures. They went back to the principles of ballasting vessels, and, as Mr. Yeoman said, sailors should have a machine to go anywhere He had seen them get as far as the Longships in going round Land's End, when it was found they had not enough engine power and had to put into Mounts Bay until the gale subsided. In his time sea-going vessels only went light for short distances, but it was now a common thing to send them out light to the River Plate. He had, however, crossed the Atlantic several times, but *never* in a light ship, and he knew full well what were the conditions and with what the poor fellows had to contend. He was pleased to think that Mr. McGlashan had struck the key-note with regard to water ballast in ships; he had also given them a more rigid ship and they would have less breakages in propeller and tunnel shafts.

Mr. E. W. De Rusett had simply a few questions to ask with regard to the pumping and other arrangements of the side tank steamer. Perhaps Mr. McGlashan would kindly state how the ballasting arrangements in connection with the side tanks would be carried out, and also the draining of the ship's midship holds and engine room, seeing that there were no limbers or wells there? Some mention was made that the weight of the ship was not increased. This was difficult to understand without explanation, but he presumed the shell had been reduced in thickness on account of the inner skin. If so, was it a wise thing to do, considering the corrosion that took place between wind and water? or possibly the type and size of vessel specially favoured the design under consideration. He would also like to know whether the side tanks would not be likely to sweat a great deal? He asked this question as he noticed that no reference had been made to side ceiling for protecting cargo in these holds, and the application of battens seemed at first sight to be somewhat costly. He thought there would be more sweat from a tank side than from an ordinary bulkhead. Would not the cost be greatly increased, considering that the ballast and engine room valve connections to the shell would have to be made through watertight pockets? Possibly Mr. McGlashan, in his reply, would give them a few figures as to the relative tonnage and capacities of the steamers quoted in the table, also how much coal would be cut out in the side tank design, as compared with an ordinary vessel, to obtain the 32 per cent. deduction for tonnage. He was glad Mr. McGlashan had brought forward the subject of water ballasting, as it was of special importance just now, when so many vessels steamed outwards in ballast trim.

Mr. A. E. Muir thought that Mr. McGlashan was to be congratulated on his very able paper, and considered it a step in the right direction as regarded the ballasting of light vessels. But the question of fitting side tanks greatly diminished the capacity of the ship's hold for cotton, etc., which was one great objection, and also the necessarily extra cost of building side tanks in comparison to the cost of the deck and beams as at present fitted in ships of this class. There was also the question of getting water-tight work in connection with the riveting, owing to the limited amount of space between the shell of ship and tank side. He also considered that the transverse strength of the vessel would be greatly diminished by the removal of the deck and beams, assuming that the side tanks would give the required amount of strength longitudinally equal to that obtained by the deck.

Mr. G. JONES said, with regard to this special type of water ballast, there could not be any difference of opinion in regard to the advisability of its being so increased; the great difficulty was how best to distribute the ballast. They had had deep tanks, but they had one disadvantage from which the first was exempt—that if they carried water ballast, they took expense to clean again. With regard to peak tanks, they had this disadvantage, that to be of any use in immersing a vessel of such a capacity, the size and weight would be such that the extreme ends of the vessel would run a great risk of straining. Mr. McGlashan mentioned a matter with regard to deck tanks. Some member present might have information upon that point. If he (Mr. Jones) was not mistaken, the tanks were all measured for tonnage. Of course the loss of capacity was saved in tonnage in the method proposed. There was one very important point about sweating. Probably some member might give them some information about the deck tank, if there was the same risk of sweating with side tanks as with deck tanks?

Mr. JAS. THOMSON said one point occurred to him, and that was the question of the effect upon the stability of the ship in the event of any accident happening to the tank. In the case Mr. McGlashan had put in his table there were about 800 tons of water ballast in the side tanks, about 400 tons on each side. Well, suppose the side was damaged, say, half of that on one side—200 tons going in on one side—that would give the ship a very great list?

Mr. MCGLASHAN—The quantity would not be so large, it would be subdivided.

Mr. THOMSON would like to ask if Mr. McGlashan had calculated what angle of inclination would be given to a ship if one side were damaged so that the water would fill one or more tanks?

Mr. MCGLASHAN—It seemed to him, if one of these compartments was injured by accident, the vessel would be much safer than if there were no side tanks, because, with a damaged ship, water could be run into the other side, and restore her to the upright position.

Mr. THOMSON—Would you get it in quick enough?

Mr. MCGLASHAN—It would not take long to get in a hundred tons.

Mr. GEORGE N. ARNISON would like to ask whether the plating of the tanks was continuous or stopped at the bulkheads?

Mr. MCGLASHAN—Continuous.

Mr. ARNISON—It should, then, be possible to reduce the thickness of the shell plating on account of the increased longitudinal strength obtained by the fitting of the side tanks. No doubt there might be some objections to side tanks; but at any rate it appeared to him that their adoption would probably hasten the time when they should have longitudinal framing and dispense with the present transverse framing, thereby obtaining greater longitudinal strength and a lighter structure, and, for all practical purposes, at least as strong as the present mercantile vessel, as was the case with warships built on the cellular system. They could continue the longitudinals through the ends of the side tanks right forward and aft, gradually reducing them in depth, if thought desirable, and so obviate the objection to having one system of framing amidships and another outside the range of the tanks, as well as distributing the increased strength obtained from the side tanks. If some such arrangement were not adopted, just beyond each extreme end of the side tanks would be a weak spot.

Mr. A. MCGLASHAN said, if agreeable, he would briefly reply to the questions put to him, and give a fuller reply at the next meeting. The subject of the paper was water ballasting of steamers; but the interest of the members seemed to centre most in the few paragraphs which referred to the side tank system of ballasting; and many of the points raised in the discussion would probably be best dealt with in another paper on some future occasion. A good deal had been said as to the reduction of capacity in the side tank steamers. In proportion to the tonnage, however, she would have more bale space than an ordinary vessel would have. Some one had spoken about grain capacity. He would remind them that the ends of ordinary ships were often bulkheaded off, and left empty when they carried sufficient grain to immerse them to the load-line. In offering steamers for carrying bale cargoes, the gross or grain capacities were frequently furnished, and the capacity of the side tank steamer might compare unfavourably with such gross or grain capacities of other ships if the relative value of the space in the two types of vessels was not explained; but charterers soon got to know the output of vessels, and assessed the value of them accordingly. Then as

to the weight of a ship with side tanks, of course there would be an increase in small ships; but in small ships there was not the same need to fit side tanks. In the side tank ship referred to, the same amount of material was required as for an ordinary vessel of the same size built to the recognised tables of scantlings, but the material was differently distributed. There was, therefore, no increase of weight, and the ship lost nothing in deadweight capacity, even though the tonnage would be reduced.

The PRESIDENT said he was sure they were all delighted with the very able paper Mr. McGlashan had read, and certainly the subject was of great interest to the Institution. During the last session they had complaints that they had only engineering papers. This session, he was glad to say, they were having shipbuilding papers, and this subject of water ballasting was most interesting. In designing a ship they had got to make a compromise and consider what the ship was going to be used for. He thought this double arrangement for water ballast in many trades presented great advantages. Of course they could not "both eat their cake and have it," and if they lost in capacity they had advantages in some other way. All ships were not built for light cargoes; and there were many trades that suggested themselves, such as the ore trade and many others, where capacity was not of moment; but where strength was important, and this appeared to him to be a very strong ship, and had the means of ballasting without too great sacrifice. He thought those questions which had been raised as to the ventilating of the double skin, painting, and so on, were very small. There was not much fear in that respect, and also as to the sweating of cargo referred to. He should think these double skins would be the very thing to avoid sweating. In regard to the general question of water ballasting of ships, and having had a great deal of experience with tank steamers, they were becoming quite familiar with the filling of ships' holds with water, and he thought shipowners and shipbuilders, too, evinced too great a fear of the effect of filling a ship's hold with water. They had met with the objection that if they were to fill a ship's hold with water they must shorten the holds and make the ship less valuable than she otherwise would be. Again, he had to say this referred only to certain trades, and if they were going to carry long rails and various other long articles, perhaps they might feel an inconvenience in limiting the length of the hold; but, on the other hand, there were a great many cargoes where there would be no detriment in curtailing the hold to a certain extent.

The objection to deep holds with small hatchways in tank steamers had been got over; they were also not so much afraid as they used to be of loose water in holds. When tank steamers were first built it was never intended that the ballast water should be let loose when crossing the Atlantic; but they had found captains (growing familiar with the subject) acting in a very reckless way by commencing to pump out the tanks in a gale of wind, and the result had been that in later ships they had had to make stronger bulkheads to withstand such treatment. This could now be foreseen and provided for, and he did not see why in large steamers their holds could not be used for water ballast, having a longitudinal centre bulkhead, which incidentally acted as a useful subdivision, and in that way they got their ships efficiently ballasted, whereas ships were often sent across the Atlantic in a condition that was simply tempting Providence.

The discussion was adjourned.

SOME CONSIDERATIONS IN CONNECTION WITH THE TRANSVERSE FRAMING OF SHIPS.

By H. E. J. CAMPS.

[Read before the Institution, in West Hartlepool, on January 15th, 1898.]

When the writer promised, a few weeks past, to read a paper before the present session of the Institution, and undertook to give one, dealing with the above subject, he did not expect to find it so broad and intricate as it is, and he considers it necessary, therefore, to apologise to the members for the apparent incompleteness of the attempt. The primary object in selecting this subject was that of inducing a discussion, by which the ideas and opinions of shipbuilders interested might be obtained, in order to throw more light on a matter which has not, to the mind of the writer, hitherto received the attention which it deserves. As to whether the results of the following investigations would be considered favourable or not is left to the members to decide, and it will be most gratifying if the remarks made may be of value to others, and call forth a discussion on a very extensive subject, which the writer himself cannot but feel it impossible to do much justice to.

There are so many different types of vessels in existence, each of which is generally designed for some particular trade, or to fulfil specified conditions, that it would be impossible to enter into a discussion on this subject for every design carried out. For a basis, therefore, upon which to work a vessel of the most common type has been taken, namely, a three-deck ship, and it will be the endeavour of the writer to discuss this ship as she would have been if built on each of the several different systems of framing.

The longitudinal and midship sections given on Diagrams i. and ii. (Plates X. and XI.) are for a vessel built two or three years ago to Lloyd's highest class on the ordinary frame and reverse frame system, in conjunction with wide-spaced hold beams. Her dimensions were :— 400 feet long between perpendiculars by 46 feet 9 inches breadth moulded and 31 feet 6 inches depth moulded.

It may be taken for granted that there are only four different systems of framing admitted by Lloyd's, and the plates represent the above vessel as she actually was, and as she might probably have been if built to the other systems.

The longitudinal and midships sections shown in Diagrams i. and ii. (Plates X. and XI.), besides representing the ordinary frame and reverse frame system, also stand for the channel and Z frames, with the exception that the frames, instead of being built up with angles, as shown in the midship section, are of Z or channel bars. Diagrams iii. and iv. (Plates X. and XII.) are to represent the same vessel as she probably would have been if built on the deep frame system, or as they are frequently called the girder frames. And Diagrams v. and vi. (Plates XIII. and XIV.) are also for the same vessel as she might have been if framed on the web frame system. As regards the two latter, of course, there must be some doubt, for it is almost impossible to tell what would happen to the plans when submitted for approval to Lloyd's Committee, as the vessel under consideration just happens to come over the grades given in their rules for deep frames, or web frames in lieu of hold beams. They would most likely ask for another bulkhead, or other extra strengthening, but, for the purpose of this paper, the plans as given will be sufficient to represent the writer's object. In each case the frames are required to be spaced 25 inches apart, and in the web frame system, the webs are not to be more than 4 frame spaces from each other.

If the elevation on Diagram i. (Plate X.) be examined, it will be seen that the main hold is the longest and deepest, and the part between frames 128 and 142 has the least support, so that it may be taken as being the weakest portion of the framing of the structure, and to that part attention has been mainly confined in each case.

The various strains to which the transverse frames may be supposed to be subject are many and varied, of which the following are a few of the worst :—The first, which is undoubtedly the worst, so far as the frames themselves are concerned, is very complex, though at first sight it appears very simple. When a vessel is laying alongside a dock wall, she will rise and fall with the tide, and be liable to being blown against the wall by the wind, or she may be thrown against it by the action of the disturbed water, and kept from coming bodily into contact by means of fenders; or she might be jammed in between the dock wall and another vessel—by no means an uncommon case ; or again, if taking in cargo from lighters, or coaling at sea off another vessel, the same thing happens, and in each case the frames are subject to very severe stresses. These stresses are of

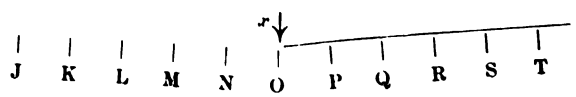
such uncertainty and magnitude that it would be of no value to choose any one as an example, and base all calculations upon it, and the most reasonable course seems to be a determination of the safe maximum load to which the frames could be subject; and that is what has been attempted in the following calculations. The figures shown in Diagram vii. (Plate XIV.) represent, as closely as necessary for our purpose, the forms which the frames will take when subjected to a concentrated load at a point midway between the two lower stringers; and this is obviously the worst condition of the load, as far as the frames are concerned. First, for the type of vessel as represented by Diagrams i. and ii. (Plates X. and XI.), Fig. 1, Diagram vii. (Plate XIV.), represents the frame acting as a beam, supported rigidly at A and B, which represent the main deck and top of tank knee respectively; C is the position of the lower deck stringer; D and E the middle and lower stringers respectively; F being the point of concentration of the load, which is assumed as being a uniformly increasing load up to the safe limit. When the load begins to take effect on the frame, it bends, as shown at Fig. 2, Diagram vii. (Plate XIV.); and as the load is a uniformly increasing load, this deflection will increase to a certain distance, or until the limit of deflection is reached, which limit will correspond to the safe load which can be placed upon the frame. But, before this limit of deflection is reached, the stringers indicated at D and E will also begin to bend under the load, and the frame will give, not only between D and E, but also between C and B, and it will assume the shape represented at Fig. 3, Diagram vii. (Plate XIV.). For the purposes of illustration, these deflections have been purposely exaggerated. Writers on the strength of materials have given the safe limit of deflection as being equal to $\frac{L}{500}$, where L is the length of the span in feet, and in the following calculations that limit has been assumed. If that deflection is exceeded, the beam has practically lost its elasticity, and continues to deflect with a constant load until it breaks—*i.e.*, if the load be great enough.

In order to save time and make matters clearer, the writer has considered it advisable to give all the calculations in detail, which will be found in an Appendix on pages 111 to 118. Those calculations have been taken on frame 135, the length of which between the main deck and the top of the tank knee is 20 feet 6 inches. The distance between A and C is 7 feet 9 inches, between C and D 4 feet 9 inches, and between D and E 4 feet 6 inches. Fig. 1, Diagram viii. (Plate XIV.) will

illustrate more clearly the distribution of the loads over the frames and stringers. Referring to the results of the calculations in the Appendix, the safe maximum load which can be placed on the frame, if it were to bend between D and E, is 7,210 lbs., for which the deflection is ·009, or only a little over $\frac{1}{10}$ inch. This being so, and the load on each of the two stringers being 3,605 lbs., if those stringers were not supported at the adjoining frames, they would be of no use whatever, for the stringers themselves, if they were only supported at the bulkheads on frames 103 and 148, are only capable of sustaining a load of 151 lbs. on D and 8·75 lbs. on E. As a matter of fact, each stringer is connected to all the frames by four $\frac{7}{8}$ inch rivets, of which the maximum strength against tearing is 52 tons, or allowing a factor of safety of 4, their strength is 13 tons. It might here be remarked that, from what is shown in the calculations, 2 rivets would be ample, as giving a support of the value of 6½ tons, and that the reverse lug usually fitted might, in the case of small stringers, be dispensed with.

It may be observed from the elevation on Diagram i. (Plate X.) that the lower deck stringer, C, is supported at frames 128 and 142, and from (7) in the Appendix the safe load on the stringer, between those two points or hold beams, is 14,600 lbs., with a deflection of ·058 from (8). As none of the safe loads on the frame, which we are considering, anyhow approach this amount, it will be quite justifiable to consider it as a fixed support for the frames, and this reduces the span from 20 feet 6 inches to 12 feet 9 inches. The main deck is undoubtedly a fixed support.

Returning to Fig. 1, Diagram viii. (Plate XIV.), having shown that if the stringers bend they must take the frames, to which they are connected, with them, and assuming that they are just capable of sustaining the pressure on them at frame O, the length over which they would have to act, if they bent to their safe limits of deflections, would be for the stringer D, 19·3 feet (from 1 in the Appendix), and for E, 4·63 feet (from 2), for which the deflections are ·0386 and ·0092 respectively (from 3 and 4), provided there was no support in between. But as has been shown, there is such support at each frame in succession, and the value of the actual support given by those frames is most difficult, if not impossible, to ascertain by calculation.



In the above figure, at the point X, is represented the load on the stringer D in Fig. 1, Diagram viii. (Plate XIV.), due to the load at the point F on frame O. The lettering at the successive ordinates on each side is for the frames, as in the same diagram. Then the reactions at the frames N and P will be greater than those at M and Q, in proportion to their deflections. As the safe limit of deflection for the stringer D is greater than that of the frame P when bending between C and B, we will assume that D bends to the safe deflection of P at P, and that the support which it receives at that frame is equal to half the total safe load on it. That is to say, the support which it gives to D is $\frac{13,980}{2}$ or 6,990, the remainder being taken up by stringer E. Quoting a few of the results given in the Appendix, if the stress on the stringer is equal to the sum of the reactions on the frames they will each be $\frac{56,083}{2} = 28,041$ lbs., to which load the stringer will, under a deflection of ·0255, act over a length of 21 feet 2 inches, in which there are 8 frames giving support. These will all be bent to something like the shape shown in the figure on page 100, which is much exaggerated, though probably they would each have a slight curvature. The sum of the reactions at K, L, M, etc., due to their deflections, if the line J O is straight, is 34,946 which only leaves it necessary for the stress on D to be equal to 21,137. The length for it to act over with this stress works out to 23 feet 4 inches, and as only the same number of frames is needed as in the 21 feet 2 inches length, the frames, instead of being spaced 25 inches apart in 20 feet 10 inches, might be 28 inches apart in 23 feet 4 inches.

So, in the first place, it has been assumed that the stringer bends to its own safe deflection independent of the frames, without which, therefore, it could only act over a length of 19·3 feet; and, in the second case, it has been assumed that the stringer bends to the safe deflection of the adjoining frame, which is less than that of the stringer in the first case, and the length over which it acts is by trial 21 feet, and by correction over 23 feet. This is for the middle stringer only.

The lower stringer, again referring to the Appendix, has only a length of 8·2 feet to work over to suit the deflection of the adjoining frame, and it has only one frame to support it on each side of O, without counting that at its extremities, which, for the calculated safe length, is expected to be fixed. But these end frames are not fixed, and with the pressure on them they would bend; and this being so, the safe deflection of N and P will be exceeded, thereby losing part of their value. This would

probably be so if there were no bilge, but owing to the great round at this part the strength of the frames is sufficiently increased to withstand such strains.

It will be observed that the assistance which the stringers give to the frames in resisting transverse strains is very important, and the difference in the value of the two lower stringers is very marked. From the calculations it would appear that, as far as the middle stringer is concerned, a wider spacing than at present carried out in the transverse frames might be adopted, as, indeed, appears from all the other stringers, with the exception of the lower one, and, as already pointed out, the round of the bilge is a very great help indeed, on account of what is known as the flexural rigidity of the frames and plating. In the Appendix will also be found a detail calculation supposing the load to be concentrated on the frame O *at* the stringer D. In that case the calculations work out a trifle more than with the load concentrated between D and E. The original lengths are about the same, but the final or corrected length is a trifle more, it being 24 feet 3 inches, and the spacing of the frames might be 29 inches. From these remarks it would be inferred that the spacing of the frames could exceed the actual, to a very fair extent, and, from what has been said, it would evidently be very unfair to consider the frames independently of the support they gain from the longitudinal girders.

Before leaving the ordinary framed ship it will be of value to notice, for a few minutes, the effect of the hold beams on the lower deck stringers. Some builders in ordinary frame ships camber these hold beams in the same manner as the deck beams, and this, in the opinion of the writer, is a mistake. The primary object of fitting these hold beams is to stay the ship's side up against compressive strains, under which they act as struts, and are, practically, under direct compression. If the beams are cambered, it is needless to observe that they have already lost the greater part of their value as struts, for long ones, such as these, do not retain much of their strength after buckling has commenced. Of course the value of the hold pillars themselves cannot be neglected, and, as is shown in the midship sections, there are three of these in the length of the beam. These beams also tie the sides of the ship together at intervals; and in ships having long holds—such as the one under consideration—combined with great depth below the lowest laid deck, such ties are very necessary. But the first of these two cases is the more important, and is the one to which special attention is drawn. In nearly every ship these beams come close down to the

neutral axis, and invariably are at the widest part of section, which is without doubt the proper position for them. The width of the vessel under consideration at this part is 46 feet 9 inches, and the safe load of the beam will be represented by the formula—

$$W = \frac{f\,S}{1 + c\,\frac{L^2}{d^2}}$$

where s = the sectional area in square inches, c = constant taken at $\frac{1}{500}$ for steel (this constant is rather a doubtful factor), f = 10,000 lbs. safe load, l = length in feet, d = the depth in feet. The value of the beam, without considering the support of the pillars, is—

$$W = \frac{10{,}000 \times 24{\cdot}4}{1 + \frac{46{\cdot}75^2}{500}}$$

$$= 45{,}437 \text{ lbs.}$$

$$= \quad 20 \text{ tons,}$$

and, with the pillars giving, say, six $\frac{7}{8}$ rivets to break, = 100 tons.

We have already seen that, taking the span between frames 128-142, the safe working load of the stringer is $101\frac{1}{2}$ tons—neglecting the support of each individual frame—or a load on each hold beam of $50\frac{3}{4}$ tons, so that there is no danger of the beam buckling with a load on the stringer at the middle of its span. But if a force were to strike the ship's side on the stringer at or close to the beam, its great value is easily seen from the above result. Thus, if a vessel is wedged between two others, as frequently happens with any vessel afloat, or in any other similar strain, these beams act a most important part in the strength of the framing, as they have to bear the greater part of such strains.

Returning to the frames themselves, we come next to the vessel built on the deep frame system, of which Diagrams iii. and iv. (Plates X. and XII.) are the longitudinal and midship sections respectively, arranged to what would probably be Lloyd's requirements for the vessel already considered under the ordinary framing system. The bulkheads have been kept the same, though probably an extra one would be required as she now comes somewhat over the highest grade included in the rules for deep frames and side stringers in lieu of hold beams. The calculations will again be found in detail in the Appendix, as far as they have gone, the same portion of the hold having been considered in order to facilitate comparisons. It is only necessary now to draw attention to the result of those calculations.

The length of the frame is 20 feet 6 inches, as before, but the spacing of the stringers is rather different, and Figs. 5, 6, 7, and 8, Diagram vii. (Plate XIV.), will represent their respective positions on the length of the frame. Referring to Fig. 2, Diagram viii. (Plate XIV.), if the load was supposed to be concentrated on the frame O, between D and E, it is seen from the Appendix that as the length of the span is only 5 feet 6 inches, the safe deflection will be ·001, and the safe load 562,184 lbs. This is equivalent to a load at D and E of 281,092, under which load the stringers will act over a length of only 5 feet or about 2½ frame spaces. The frame O will deflect and take the stringers D and E with it. Also the frames N and P, will not be able to withstand the pressures exerted on them from the stringers D, E, in consequence of which they will both bend between C and B. But the depression will probably not cease at the frames N and P, but be further carried on to M and Q, before reaching which points, the actual pressure on the frames becomes very vague. For this case, then, the loads being very much distributed, the effect of the stringers in taking them up and transferring them to the adjoining frames, is so complicated that the strength of the whole network of frames and stringers is practically impossible of solution by calculation, and could only be approximated with any degree of accuracy by experiment.

And again, if the load was concentrated on the stringer D at frame O, the calculations are as doubtful as with the load between D and E, for when once the stringers C and E become affected it is impossible to tell how the pressures are distributed over the system

These remarks will explain the apparently unfinished condition of the calculations in the Appendix.

The last system to deal with for this particular strain is the web-frame system, Diagrams v. and vi. (Plates XIII. and XIV.), and which is more plainly shown in Fig. 3, Diagram viii. (Plate XIV.). An examination of that diagram will show that as far as the web frames themselves are concerned the same remarks will hold as were made in the case of the deep framed ship, and the strength of the system of the network of web frames and stringers is practically impossible of calculation. It will, however, be interesting to show how very materially the ordinary frames of a ship are affected by the web frames, for which purpose only a short investigation is necessary.

If the load was concentrated at midway between D and E, as shown in Fig. 6, Diagram vii. (Plate XIV.), the safe maximum load is—

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 117 \times}{(5{\cdot}5 \times 12)^3} \frac{5{\cdot}5 \times 12}{500}$$
$$= 74{,}980 \text{ lbs.},$$

and this is equal to a reaction on the stringer of 37,490 lbs. The stringer is capable of resisting a pressure—

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 712 \times}{(8{\cdot}3 \times 12)^3} \frac{8{\cdot}3 \times 12}{500}$$
$$= 202{,}200, \text{ about},$$

with a deflection of—

$$d = \frac{8{\cdot}3}{500}$$
$$= {\cdot}0166.$$

And this is considerably over what the frame is capable of producing on the stringers. The effect, therefore, of a load acting at the middle of such a span as that between D and E on the ordinary frame in the web frame ship would be to bend the frame only before the stringers or web frames would be affected to any appreciable extent. And if the load was greater than the safe load of 74,980 lbs. given above, the frame would still bend, and probably give way altogether before the stringer would be materially affected, and this would be the case on any individual frame at any part of the ship except at the web frames. A table (page 110) is given with the Appendix, in which the scantlings of the frames to the different systems is given for the vessel which has been considered, and in it are given, for purposes of reference and comparison, the moments of inertia of the frames with and without the shell plating, and their respective moments of resistance in inch-tons. There is also given the same information for the stringers of each of the different systems. The influence of the shell plating, when taken into account, is very marked, especially in the case of the web-frame ship. In that latter the shell plating has the effect of more than trebling the moment of inertia. The great difference between the frames of the deep frame ship and the side stringers for the same system is worthy of note, as indicating rather a waste of material in the latter for the comparative strength. It hardly comes within the lines of this subject, or the writer would have liked to have dealt with these stringers and their relative weights and efficiency.

It is sometimes thought that the pressure of the water acting on the sides of a ship produces a heavy strain on the transverse frames. There is, of course, a certain amount of strain on the ordinary frame, especially just above the bilge where the water would have the greatest effect. In

the vessel which we have been considering, the pressure of the water on the frame might be taken as being concentrated at a depth of 13 feet, at which point the pressure is 5·64 lbs. per square inch. Or, in other words, the frame, neglecting the stringers entirely, might be considered as a beam supported at both ends and loaded at 14 feet from A, taking frame 135 as before. The load on it at 13 feet down is 5·64 by 25 or 141 lbs. The 13 feet is taken at $\frac{2}{3}$ the depth of the water to the top of the tank knee. The actual bending moment due to this load is only about ·3 foot-ton, whereas the maximum moment of resistance is 28 foot-tons according to the table, from which it can be seen that there is a very large margin of safety.

There are several very important considerations to take into account in discussing the possibilities of a wider spacing of frames than is at present adopted, most of which have been dealt with at various times, and which will only be mentioned in the following remarks. But, first, the writer would like to draw attention to the effect of a wide spacing of frames on skin plating when subjected to compressive strains. When a vessel is riding over waves the upper and lower works are subjected to tensile and compressive strains alternately, alternating when on the crest of a long wave or in the hollow. It is when the plating is in compression that the frames are of the greater importance, and special attention should be given to this consideration. It is clear that, unless the plating is well supported at sufficient intervals, the stress on the material cannot be very great, and to show the difference it is proposed to assume the possible spacing of frames given in the Appendix for system A, and compare it with the 25 inch spacing, the possible being 29 inches. The average thickness of the outer bottom plating near the keel is about $\frac{13}{20}$, and at the top there is a complete steel upper deck of $\frac{8}{20}$ thickness amidships. Both the tank floor and the beams are spaced 25 inches apart, and the safe load on the plating will be obtained by the formula for pillars fixed at both ends, as in the case of the hold beams, viz. :—

$$W = \frac{f\,s}{1 + c\,\frac{l^2}{d^2}}.$$

Taking a strip 12 inches wide in each case, we have for the bottom plating—

$$W = \frac{10{,}000 \times 7{\cdot}8}{1 + \frac{2{\cdot}083^2}{2{,}400 \times {\cdot}0541^2}}$$

$$= 48{,}042 \text{ or } 6{,}159 \text{ lbs. per square inch.}$$

And for the deck plating—

$$W = \frac{10{,}000 \times 4{\cdot}8}{1 + \frac{2{\cdot}083^2}{2{,}400 \times {\cdot}0333^2}}$$

$$= 18{,}154 \text{ or } 3{,}780 \text{ lbs. per square inch.}$$

That is, taking C to be of the value of $\frac{1}{2400}$.

If the spacing were to be 29 inches, the value for the bottom plating is—

$$W = \frac{10{,}000 \times 7{\cdot}8}{1 + \frac{2{\cdot}416^2}{2{,}400 \times {\cdot}0541^2}}$$

$$= 42{,}542 \text{ or } 5{,}454 \text{ lbs. per square inch.}$$

And for the deck plating—

$$W = \frac{10{,}000 \times 4{\cdot}8}{1 + \frac{2{\cdot}416^2}{2{,}400 \times {\cdot}0333^2}}$$

$$= 15{,}014 \text{ or } 3{,}128 \text{ lbs. per square inch.}$$

From these figures will be seen the great difference in the stress per square inch caused by even so small a difference as 4 inches in the spacing of the frames. In the case of the bottom plating a difference of 700 lbs. per square inch, and in the deck plating 650. Of course, if a wider spacing of frames was wished for, this deficiency could be overcome, if necessary, by increasing the thickness of the plating. As to the real necessity for such increases being made in the thickness to compensate for wide spacing of frames, there is a great diversity of opinion. If it is safe to go by the experience of vessels already at sea, there does not appear to be any necessity; for it is well known that in war vessels, and in a few merchant vessels which are not classed, the spacing very considerably exceeds what would be required by the registration societies, and that without causing any apparent weakness in the structure. The question resolves itself into what should be the maximum stress per square inch on the shell plating when subjected to compressive strains. If that point were settled it would be a matter of pure scientific investigation into the maximum hogging or sagging strains to which any vessel would be subjected in her working conditions; the stress on the material could then be found, and the frames spaced accordingly.

Another consideration in connection with the frames and their effect on the plating is that in which their relation to the shift of butts is of great importance. This subject was very fully dealt with in a valuable paper read before the Institution of Naval Architects in April, 1873, by W. H. White, Esq. (now Sir William). For the theoretical consideration of this point the writer cannot do better than refer those interested to that

paper, which will be found in the *Transactions* of the Institution, vol. xiv. Although written over twenty years ago, there is sufficient evidence in the construction of our present war vessels to indicate that its author has had no cause to change his opinion as to the desirability of adopting a wider spacing of frames; and the opinion of our leading expert in naval construction should carry great weight. At the time it was written the plates in use were very short, and the shift of butts had to be carefully manœuvred; but at the present day, with the great convenience of machinery and the long plates which can be obtained, the shift of butts is much simplified, although it will always be a source of a certain amount of worry to the draughtsman who has to arrange them; but a wider spacing of frames would be of no assistance in this respect.

In another paper read before the Institution of Naval Architects, in March, 1891, by J. A. Yates, Esq., the influence of the water pressure on the skin plating and the effect of the frames was fully discussed, and for this also the writer would refer those interested to the paper, which will be found in vol. xxxii. of the *Transactions*. There is no doubt that the consideration of water pressure is of great importance, especially in merchant vessels of deep draught, and the theoretical investigations of Mr. Yates resulted in showing that the possible spacing of frames was practically the same as that obtained for the ordinary framed ship in the present paper. From the discussion which followed that paper it would be inferred that the gentlemen who took part in it rather considered the spacing given as being too close, but for the object of the present paper the results of Mr. Yates are sufficient to indicate its importance.

There are other strains to which the frames are subjected which might be theoretically considered, such as the influence of loads placed on the deck, tending to crush the frames, and distort them at the bilges, or top and bottom stresses of the tank knees; and again the strain on the frames due to racking when the vessel is rolling; but it would make this paper too long to go into them, and as they are probably not of so much importance as those already mentioned, the writer does not propose to consider them.

Before leaving the subject it will be of advantage to draw attention to one or two more practical considerations which are worthy of notice.

The most important of these is the great saving in weight which would obviously be effected if a wider spacing of frames than at present could be adopted with the same thicknesses of shell plating; and not only the great saving in weight, but in labour also. If a spacing of 29 inches could be adopted in a vessel like that shown in Diagrams i. to vi. (Plates

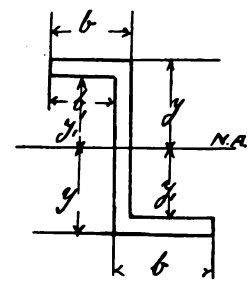
X. and XIV.), a probable saving in weight of over 15 per cent. on the frames would not only reduce the first cost of the ship to a very great extent, but the shipowner would find the carrying capacity on the same draught very profitably increased.

Apart from the saving in weight and labour there are such considerations to account for as the efficiency of the caulking if the frame spacing was increased, and the greater conveniences in working other material into the ship which would be obtained by such an increase. In support of these the writer can only refer to the actual results obtained in other vessels which have been built, particularly those of the Royal Navy.

Summing up the results obtained, it is seen that, considering the frames as though they were subjected to concentrated loads—first, between two stringers; second, on a stringer, provided the frame is not stressed beyond its safe limit of deflection, that is to say, if the load is just sufficient in each case to bend the frame within its limit of elasticity—the spacing of the frames, as far as they themselves are concerned, could very much exceed the spacing at present required by the registration societies to the extent of 3 or 4 inches in such a vessel as the one considered. The very great importance of the hold beams and the desirability of close spacing of bulkheads is also very prominent. The next result obtained shows that the pressure of the water itself on the frame is also very much below the safe limit of stress on the frame, and that therefore, as far as the frame itself is concerned, the water pressure is of no consequence. The water pressure is only of great importance when considered as acting on the shell plating in one frame space, as was shown in the paper of Mr. Yates referred to. The marked difference between the maximum stresses in the plating, when the vessel is under hogging or sagging strains, caused by a difference of 3 or 4 inches in the spacing of the frames, is interesting, this amounting in the vessel considered to as much as 700 lbs. per square inch. The practical considerations are well enough known to all shipbuilders to make it unnecessary to enumerate them here, and it is left to the meeting to decide whether the whole of the considerations, taken collectively, are in favour of a wider spacing of frames than admitted by the registration societies.

Finally, considering the great strides which have been made in steel shipbuilding, and with the introduction into the industry of so many different types of vessels, it is unlikely that builders will continue to build vessels to hard and fast rules, but they are more likely to investigate the possible strains for each ship, and base the scantlings on the result of these calculations, particularly now that foreign competition is becoming so keen, and expenses have to be kept as low as possible.

TABLE.

System	Section.	Description.	Moment of Inertia = I.	Moment of Resistance in Inch-tons.	Sectional Area. Square Inches.	Stringers.	Moment of Inertia = I. *	Moment of Resistance in Inch-tons. †	Sectional Area. Square Inches.	Formulæ.
A		6 × 3½ × $\frac{10}{20}$ frame ... ... 4½ × 3½ × $\frac{9}{20}$ reverse frame...	35	353	7·9	Lower deck	9,834	16,841	33·94	
		Do. with shell $\frac{13}{20}$	117	531	24·15	Middle ...	1,070	3,366	18·9	
		6 × 3½ × 3½ × $\frac{12}{20}$	36	338	7·08	Lower ...	62	372	13·425	
		Do. with shell $\frac{13}{20}$	116	525	23·33					
B		6 × 3½ × $\frac{10}{20}$ F. } Girder 6½ × 3½ × $\frac{9}{20}$ R.F. } 9½ in.	281	1,564	8·8	Upper Middle Lower	386	1,491	28·25	
		Do. with shell $\frac{13}{20}$	876	2,541	25·05					
C		Frame, 6 × 3½ × $\frac{10}{20}$ ... ... Face bars, 4½ × 3½ × $\frac{9}{20}$ ... Web plate, 22 × $\frac{10}{20}$	1,476	4,750	22·3	Upper Middle Lower	712	4,330	18·2	
		Do. with shell $\frac{13}{20}$	4,586	6,270	38·55					

* Moment of inertia = $I = \frac{2}{3}(by^3 - b_1y_1^3)$. † Moment of resistance = $\frac{28\ I}{y}$.

APPENDIX.

Formula used in the following calculations :—

$$\text{Safe deflection} = d = \frac{WL^3}{48EI} \text{ and } d = \frac{L}{500};$$

$$\text{„ length due to } d = L = \sqrt{\frac{12EI}{W \times 125}} = \sqrt[3]{\frac{48EId}{W}};$$

$$\text{„ load} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad = \frac{48EId}{L^3};$$

where E = modulus of elasticity, taken at 13,000 tons ;
I = moment of inertia of the section (see table) ;
W = weight in lbs. ;
L = length in feet.

System A.

First.—Position of load on frame O between D, E, Fig. 1, Diagram viii. (Plate XIV.) :—

Length of span, D — E = 4·5 feet = 54 inches,

$$\therefore d = \frac{4{\cdot}5}{500} = {\cdot}009,$$

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 117 \times \frac{4{\cdot}5 \times 12}{500}}{(4{\cdot}5 \times 12)^3}$$

$$= 112{,}166 \text{ lbs.};$$

length of lower and middle stringers, between the water-tight bulkheads, is 94 feet, and for the lower stringer,

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 62 \times \frac{94 \times 12}{500}}{(94 \times 12)^3}$$

$$= 136 \text{ lbs.};$$

and for the middle stringer,

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 1{,}070 \times \frac{94 \times 12}{500}}{(94 \times 12)^3}$$

$$= 2{,}350 \text{ lbs.};$$

reaction at D and E, Fig. 2, Diagram vii. (Plate XIV.), due to load F,

$$= \frac{112{,}166}{2} = 56{,}083 \text{ lbs.}$$

Thus, the excess over the safe load, supposing the stringers were not supported at adjoining frames, but free for the entire length of 94 feet, would be quite beyond the strength of the stringer, as—

$$D = 56{,}083 - 2{,}350 = 53{,}733;$$
$$E = 56{,}083 - 136 = 55{,}947.$$

The length over which the middle stringer will act, assuming that it is just capable of supporting its load of 56,083 lbs., to a deflection of $\frac{L}{500}$ without any support between,

$$L = \sqrt{\frac{12 \times 13{,}000 \times 2{,}240 \times 1{,}070}{125 \times 56{,}080}} \div 12.$$

(1) . . . . . = 19·3 feet.

And for the lower stringer,

$$L = \sqrt{\frac{12 \times 13{,}000 \times 2{,}240 \times 62}{125 \times 56{,}080}} \div 12.$$

(2) . . . . . = 4·63 feet.

Maximum safe deflection for middle stringer,

$$d = \frac{19{\cdot}3}{500}.$$

(3) . . . . . = ·0386.

And for lower stringer,

$$d = \frac{4{\cdot}63}{500}.$$

(4) . . . . . = ·0092.

Second.—Position of load on frames N and P, between C-B, or equally on D, E. (See Fig. 4, Diagram vii., Plate XIV.)

Length of span = 12·75.

$$d = \frac{12{\cdot}75}{500}.$$

(5) . . . . = ·0255.

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 117 \times}{(12{\cdot}75 \times 12)^3} \frac{12{\cdot}75 \times 12}{500}$$

(6) . . . . = 13,980 lbs.

Length of lower deck stringer between hold beams = 29 feet, and

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 9{,}834 \times}{(29 \times 12)^3} \frac{29 \times 12}{500}$$

(7) . . . . = 227,240.

Maximum safe deflection for lower deck stringer,

$$d = \frac{29}{500}.$$

(8) . . . . = ·058.

Deflection of stringer D at frame N or P,

$$d = \frac{9{\cdot}65 - 2{\cdot}08}{9{\cdot}65} \times {\cdot}0386$$

$$= {\cdot}0302.$$

And of stringer E at frame N or P,

$$d = \frac{2{\cdot}31 - 2{\cdot}08}{2{\cdot}31} \times {\cdot}0092$$
$$= {\cdot}0009,$$

i.e., a mean deflection of ·0155 on N or P, for which the load is

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 117 \times {\cdot}0155 \times 12}{(12{\cdot}75 \times 12)^3}$$
$$= 8{,}430,$$

which from (6) is a margin of 5,550 lbs. on the frames N and P, due to the load at F on O.

Third.—From Fig. 1, Diagram viii. (Plate XIV.), the load on D or E at frame O = 56,083.

Let resistance of stringer D be called f, and the sum of the reactions of the frames, N, P, Q, R, etc., be called R.

Then the load on $D = W = 56{,}083$,

and $W = f + R$,

$$W - R = f.$$

To arrive at R, assume

$$f = 28{,}041,$$

and that D will bend to the deflection of N, and P = ·0255 (from 5); then the length over which the stringer should act will be

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 1070 \times {\cdot}0255 \times 12}{28{,}040}} \div 12$$
$$= 21{\cdot}2,$$

i.e., a little over the ordinary even frame space, which is 20 feet 10 inches. But if there is a support at the extremities of this length of 21·2, there is a correction to make, for there are four frames between each end and the point F, and the values of the reactions of these frames to their several deflections will be as follows :—

$$N = 6{,}990,$$
$$M = 5{,}241,$$
$$L = 3{,}495,$$
$$K = 1{,}747,$$
$$\overline{}$$
$$17{,}473,$$
$$\therefore\ R = 34{,}946.$$

(NOTE.—The writer has here for simplicity neglected to take into account the fact that if the stringer were to bend until the frame N had reached its maximum safe deflection, its own deflection will be slightly more, and its equivalent load a little greater.)

Correcting the length to this, we get for D,

$$W - R = f,$$

$$56{,}083 - 34{,}946 = f,$$

$$f = 21{,}137,$$

then $$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 1{,}070 \times \cdot 0255 \times 12}{21{,}137}} \div 12$$

$$= 23 \text{ feet } 4 \text{ inches},$$

i.e., instead of 20 feet 10 inches, we might with safety have 23 feet 4 inches with the same number of frames.

Fourth.—In the case of the lower stringer,

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 62 \times \cdot 0255 \times 12}{28{,}040}} \div 12$$

$$= 8\cdot 2 = \text{about 4 frame spaces.}$$

Here there is only one frame bent which will be of the value of 6,990 lbs., viz., N, which is now at its safe limit of deflection.

Then $$W - R = f,$$

$$56{,}083 - 13{,}980 = 42{,}103 = f$$

$$= \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 62 \times \cdot 0255 \times 12}{42{,}103}} \div 12$$

$$= 7\cdot 15\,;$$

and this result is less than before, so that the frames, not having sufficient resistance, would exceed their safe deflection. This would probably be so if the sides were perpendicular, but the round of the bilge at this part more than compensates for this weakness.

Fifth.—Position of load, concentrated on D, at frame O,

Length of span $= 9\cdot 25$,

$$\therefore\ d = \frac{9\cdot 25}{500}$$

$$= \cdot 0185,$$

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 117 \times \frac{9\cdot 25 \times 12}{500}}{(9\cdot 25 \times 12)^3}$$

$$= 26{,}546,$$

$$R + f = 53{,}092\,;$$

but in this case the reaction on the stringers C and E = 830 and 880 respectively, and from (7) C = a fixed point, therefore E need only be considered in conjunction with D. Then for D,

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 1{,}070 \times \cdot 0185 \times 12}{26{,}546}} \div 12.$$

(9) . . $= 19\cdot 4$,

$$d = \frac{19\cdot 4}{500}.$$

(10) . . $= \cdot 0388$.

$$\text{Reaction on stringer E} = \frac{4{\cdot}75}{9{\cdot}25} \times 26{,}546 = 13{,}631,$$

$$L = \sqrt{\frac{12 \times 13{,}000 \times 2{,}240 \times 62}{125 \times 13{,}361}} \div 12.$$

(11) . . . . . $= 9{\cdot}4,$

$$d = \frac{9{\cdot}4}{500}.$$

(12) . . . . . $= {\cdot}0188.$

Deflection of stringer D at N or P,

$$d = \frac{9{\cdot}7 - 2{\cdot}08}{9{\cdot}7} \times {\cdot}0388$$

$$= {\cdot}0304.$$

And of stringer E at N or P,

$$= \frac{4{\cdot}7 - 2{\cdot}08}{4{\cdot}7} \times {\cdot}0188$$

$$= {\cdot}0104,$$

i.e., a mean deflection at N or P of ·0204, to which the load is

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 117 \times {\cdot}0204 \times 12}{(12{\cdot}75 \times 12)^3}$$

$$= 11{,}180,$$

which from (6) is a margin of 2,800 lbs.

Sixth.—Again referring to Fig. 1, Diagram viii. (Plate XIV.)—

f of stringer D $= 26{,}546,$

R of frames $= 26{,}546$;

and again assuming that D will bend to the deflection of N or P = ·0255 from (5),

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 1{,}070 \times {\cdot}0255 \times 12}{26{,}546}} \div 12$$

$$= 21{\cdot}5.$$

Thus, as in the previous case, the length is a little above the original, and making the correction in the same way as before we have

$$R = 34{,}946.$$

Total, $W = 26{,}546 + 26{,}546 = 53{,}092,$

$\therefore \quad 53{,}092 - 34{,}946 = 18{,}146.$

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 1{,}070 \times {\cdot}0255 \times 12}{18{,}146}} \div 12$$

$$= 24{\cdot}2,$$

i.e., instead of 20 feet 10 inches, we might have 24 feet 3 inches and the same number of frames with safety. In the case of the lower stringer,

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 62 \times {\cdot}0255 \times 12}{6{,}815}} \div 12$$

$= 13{\cdot}1$, or a little over 6 frame spaces,

in which the value of R would be 20,970. But the actual load is only 13,631, and the value of f for E is 6,815; so that there is therefore more than twice as much strength as is required, without counting on the assistance from the frames due to the form at the bilges.

SYSTEM B.

First.—Position of load on O between D and E, Fig. 2, Diagram viii. (Plate XIV.):—

Length of span $= 5{\cdot}5$,

$$d = \frac{5{\cdot}5}{500}$$

$$= {\cdot}011,$$

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 876 \times 5{\cdot}5 \times 12}{(5{\cdot}5 \times 12)^3 \quad 500}$$

$$= 562{,}184.$$

The length of the stringers between the water-tight bulkheads is 94 feet, and therefore for each one we have

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 386 \times 94 \times 12}{(94 \times 12)^3 \quad 500}$$

$$= 848 \text{ lbs.}$$

Reactiсn at D and E,

$$= \frac{562{,}184}{2}$$

$$= 281{,}092.$$

The length over which the stringers D and E will act, assuming that they are just capable of supporting their respective loads of 281,092 lbs. to a deflection of $\frac{L}{500}$ without any support from the frames between, will be

$$L = \sqrt{\frac{12 \times 13{,}000 \times 2{,}240 \times 386}{125 \times 281{,}092}} \div 12.$$

(1) . . . . . $= 5{\cdot}15$,

or about $2\frac{1}{2}$ frame spaces; and

$$d = \frac{5{\cdot}15}{500}.$$

(2) . . . . . $= {\cdot}0103.$

Second.—Position of load on frames N and P between C and B, or equally on D, E. (See Fig. 6, Diagram vii., Plate XIV.)

Length of span = 15 feet,

$$d = \frac{15}{500}.$$

(3) . . . . . $= \cdot 03$,

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 876 \times}{(15 \times 12)^3} \frac{15 \times 12}{500}$$

(4) . . . . . $= 75{,}582$.

Third.—Position of load on D :—

Length of span = 11 feet,

$$d = \frac{11}{500}.$$

(5) . . . . . $= \cdot 022$,

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 876 \times}{(11 \times 12)^3} \frac{11 \times 12}{500}$$

(6) . . . . . $= 140{,}270$.

The total resistance to bending = 140,270 lbs. for the stringer + 140,270 lbs. for the resistance of the frames = 280,540. Reaction at C and E due to the load on D $= \frac{140{,}270}{2} = 70{,}135$.

For C and E therefore

$$L = \sqrt{\frac{12 \times 13{,}000 \times 2{,}240 \times 386}{125 \times 70{,}135}} \div 12.$$

(7) . . . . . $= 10 \cdot 2$,

i.e., about 5 frame spaces ; and for D,

$$L = \sqrt{\frac{12 \times 13{,}000 \times 2{,}240 \times 386}{125 \times 140{,}270}} \div 12.$$

(8) . . . . . $= 7 \cdot 25$.

The safe deflections for C and E,

$$d = \frac{10 \cdot 2}{500}.$$

(9) . . . . . $= \cdot 0204$,

and for D,

$$d = \frac{725}{500}.$$

(10) . . . . $= \cdot 0145$.

The safe load on O between A and B, if not supported by the stringers C, D, E,

$$W = \frac{48 \times 13{,}000 \times 2{,}240 \times 876 \times}{(20 \cdot 5 \times 12)^3} \frac{20 \cdot 5 \times 12}{500}.$$

(11) . . . . $= 40{,}466$.

Fourth.— f on stringer D = 140,270,
" " E = 70,135,
" " C = 70,135.

If, as in System A, we assume that the stringers will bend to the safe deflection of N and P $= \frac{20 \cdot 5}{500} = \cdot 041$, we have for the stringer D,

$$L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 386 \times \cdot 041 \times 12}{140{,}270}} \div 12$$

$$= 10 \cdot 3 \text{ feet,}$$

i.e., about 5 frame spaces. As the extreme ends come beyond the frames, we may assume that the value of the reaction of the frames is as follows :—

$$\begin{aligned} P &= 40{,}466 \\ a &= 20{,}233 \\ \hline & \ 60{,}699 : \end{aligned}$$

and the correction in the length becomes : —

$$\begin{aligned} \text{As } W &= R + f \\ &= 140{,}270 + 140{,}270 \\ &= 280{,}540, \\ W &= 280{,}540 - 121{,}398 \\ &= 159{,}142 ; \end{aligned}$$

$$\therefore L = \sqrt[3]{\frac{48 \times 13{,}000 \times 2{,}240 \times 386 \times \cdot 041 \times 12}{159{,}142}} \div 12$$

$$= 9 \cdot 87 ;$$

and this result is less than before, which is impossible, practically. The figures are given, but the writer has only done so to show the impossibility of determining the actual distribution of the loads by calculation.

DISCUSSION.

Mr. Robert Thompson was sure they were all very much obliged to Mr. Camps for the able paper he had written. Its importance, to his mind, was that this wide spacing of frames given with certain vessels, showed that these calculations were being worked out by shipbuilders. There was an impression abroad that certain things were sent out with the idea of putting them through ; but he thought such Institutions as this, and the discussions they had, showed clearly that the various calculations necessary for the different strains that steamships were subject to were gone into carefully, and the relations of strength to these calculations were fully considered. He had always been in favour of

wider spaced frames: they had one vessel running now with 30 inches instead of 28 inches, and she had never been out of the Atlantic trade, summer and winter. He did not say whether she was approaching the form already spoken of, "getting from the ship to the box or the box to the ship again;" but in this case they had never had any complaint, and it seemed to him, in the midship of vessels, they could do with wider spaced frames, even if they closed the places aft and forward as was pointed out. They wanted a uniform ship fore and aft without any point being particularly rigid. When the strength was applied uniformly, it was astonishing what a ship would bear, and he was sure such a paper as Mr. Camps had read showed, to his mind, the great advance in shipbuilding construction, because shipbuilders were often blamed for things with which they had nothing to do. They complained of ships not having sufficient water ballast. He thought shipbuilders had to build the ships as they were told, and make the best of it; but the various questions that came before shipbuilders to-day, and which were discussed with the shipowners, were very much more numerous and important than they used to be; but generally, when they got an order for a ship, she had to carry so much deadweight, and have so much cubic capacity, and had to run a certain speed. The owners' requirements had to be fulfilled, and anyone who took the trouble of reading this paper must be struck with its practical and scientific points, all tending to the advantage of the shipowners. He agreed with the President, that they had this session a series of shipbuilding papers, which were not only a credit to the writers, but a credit to the Institution.

Mr. G. JONES said the paper required some study in order to compare the statements with the tables. He thought the step proposed was in the right direction, and what the registration societies and all shipbuilders required to do was not to go to extremes all at once, but to have a ship to stand the greatest strains, having regard to both weather and loading. Still he thought the tendency was to extend the frame spacing, and he thought papers of this sort ought to make some impression on the registration societies. There would, no doubt, be some gentlemen present from Lloyd's who, he hoped, would work in this direction. Let them try to work with the registration societies in a way to secure economy with the best distribution of material.

The discussion was adjourned and the meeting terminated.

---

su
calcu

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897-98.

PROCEEDINGS.

INSTITUTION DINNER.

The Institution Dinner of the North-East Coast Institution of Engineers and Shipbuilders was held on the evening of Friday, February 4th, 1898, in the Assembly Rooms, Westgate Road, Newcastle-upon-Tyne.

There was a large and influential gathering. The chair was occupied by the President of the Institution (Col. H. F. Swan), the vice-chair by Mr. J. R. Fothergill (Chairman of the Dinner Committee), and amongst those present were the following:—Messrs. W. Boyd, Wigham Richardson, and Robert Thompson, Past-Presidents; the Mayor of Newcastle (Ald. T. B. Sanderson), the Mayor of Hartlepool (Mr. T. Mudd); Messrs. Henry Fownes, J. M. Rennoldson, and Prof. R. L. Weighton, Vice-Presidents; Principal Gurney, Capt. Lin Kok Cheong and Captain Chen (Chinese Navy), Mr. H. J. Bendixen (supervising engineer to the Royal Norwegian Navy), Capt. M. Uchida and Mr. T. Merd (Japanese Navy), Mr. Janssen; W. H. Dugdale, J. B. Furneaux, J. H. Heck, S. Hunter, R. H. Muir, P. Phorson, C. Rennoldson, M. Sandison, W. G. Spence, J. Walker, and R. Wallis (Members of Council); Mr. G. Russell (President of the Institution of Engineers and Shipbuilders in Scotland), Mr. L. W. Adamson, Mr. J. D. Wardale (President of the Students' Association of Civil Engineers), Messrs. J. Duckitt (Secretary), John Bulmer, John Price, W. Swinburne, J. C. Nicholson, W. G. Reynolds, D. C. Beadon, J. M. Robson, C. H. Reynolds, E. Scott, A. G. Schaeffer, H. Quicke, H. E. Hollis, J. W Robson, W. F. Snowdon, J. Nixon, F. Graham, W. W. Maxwell, F. Lewins, G. E. Macarthy (Hon. Treasurer), D. Myles, J. W. Reed, J. D. Christie, R. A. Lewins, J. H. K. McLean, J. M. Allan, G. T. Duncan, J. Stewart, W. Swinney, P. H. Winstanley, H. MacColl, S. Harrison,

W. Mills, E. T. White, R. S. White, J. T. Batey, R. Christie, G. Arnison, A. J. Harrison, T. Townes, J. Nodder, C. Cairns, S. E. Hurndale, J. Houston, H. Charlton, W. Scott, C. H. Tate, J. S. Nicholson, R. Fletcher, J. Matthews, T. E. Smith, C. A. Bushell, J. Armit, J. S. Barr, H. W. Willcox, P. F. Willcox, D. N. Brims, C. Storey, G. J. Carter, E. J. Crosier, T. Metcalfe, H. Laing, L. Rusden, B. Morton, R. Fletcher, J. Tweedy, R. L. Gaine, A. Jenkins, R. Park, J. Bailey, C. J. Seaman, H. Ward, R. Philipson, A. Laing, A. E. Doxford, J. Reed, J. K. Sinton, T. Millar H. B. Rowell, J. Thompson, J. Knott, M. Dillon, L. Evans, R. Muir, G. F. Mulherion, and others.

After the loyal toasts,

The Rev. Principal GURNEY proposed "The Institution." In doing so he said it was indisputable that there were no industries more important for the welfare of this country than those of engineering and shipbuilding. If Great Britain was to maintain her eminent position among the nations, the quality of that work must be kept up. If the world was to go to America for its engines and to Germany for its ships, it would be a bad day for this island. They had therefore every reason to heartily wish prosperity and success to their engineers and shipbuilders. They were very proud of the many able men that the North-Eastern district of England had produced. They rejoiced to find that the present generation were proving themselves worthy successors in the work of those honoured names who would ever live in the history of invention. They were met together upon a memorable occasion. The clouds which had darkened the horizon for so many months appeared to have dispersed. They trusted that they were entering upon a long period of industrial peace and commercial prosperity. At the cost of very great sacrifices the engineers had rendered very great service to their country. They had taught the nation an important truth. They had disproved the false doctrine that labour and capital were necessarily antagonistic. They must work together for the common weal. They could only do their proper work when they were directed by the master minds. The rights of workmen had been fully recognised, but the duty had been asserted and accepted by both sides, that a man had not only a right, but that it was his duty to manage his own business in the way that he considered to be best. They were proud to believe that the workmen of this country were the finest in the world, but for them to do less than their best was

unworthy and was immoral. Such a policy could only lead to ruin and disaster in these days of fierce competition in every country of the world. Foreign nations had, to a certain extent, anticipated this country in recognising the very close connection which existed between education and commercial success. The importance of this question, however, was now being recognised in this country not only by educational experts and enthusiasts, but by practical and shrewd men of business. He alluded to the chair of naval architecture at the local College of Science, which was so ably filled by Prof. Weighton. He mentioned that although their Institution was one of the youngest engineering institutions in this country it now numbered about 1,020 members. A most valuable work had been done by it in advancing the knowledge of the principles and the practice of their art. He coupled with the toast the name of Colonel Swan, their President—a gentleman who had for many years presided with conspicuous ability and remarkable success over a very important branch of the work of the great Armstrong firm.

The PRESIDENT (Colonel H. F. Swan), in responding, said they had seen that Institution grow from very small beginnings to be recognised as one of the most important in the kingdom. The educational work which it had been doing for a great many years had been of the greatest benefit to that district. If one went back to the time, say when he commenced shipbuilding, the scientific part of shipbuilding was very little understood, but nowadays it would be the exception for any shipyard of importance not to have a most important scientific staff, and even the junior draughtsmen were well acquainted with the scientific rules relating to the business in which they were engaged. This had been of immense importance to this district. Now they saw turned out from shipyards on the North-East Coast vessels of all descriptions. There was nothing too important for them to deal with in local shipyards. This had only been attained by applying in a practical manner the scientific training that was being diffused amongst the staffs of the leading manufacturers in the district. It had been remarked that their Institution had already grown to have more than 1,000 members, and it was a matter of great pride to him that this had happened during his term of office. He could only hope that the Institution would go on and prosper, and that they might see its membership doubled before many years longer. There was no reason why this should not be. Trade was growing every day, and they were seeing new developments and extensions of industries in all departments. He feared that their

connection with those scientific institutions was not altogether unselfish. To a certain extent they looked upon those institutions as a means to an end. That was to bring to bear in their daily avocations the scientific truths that they learned from those institutions, and so extend their operations and induce business, which he need not say was the object of their calling in that district, and, in fact, he might say in all districts.

Mr. W. Boyd gave "Kindred Institutions," coupled with the name of the President of The Institution of Engineers and Shipbuilders in Scotland (Mr. G. Russell), and after some preliminary remarks, added the rules of their Institution debarred discussion or special reference to trade questions; but he could not help observing that recent events in connection with the dispute in the engineering trade, which was now happily ended, had been the means of promoting mutual confidence and goodwill between employers engaged in engineering work in various parts of the country, which he thought would be found to be for the benefit of the country at large.

Mr. George Russell, who was warmly received, responded. He urged that these "Kindred Institutions" were of great value to each other by interchange of transactions, as in any one of the institutions each individual member had the benefit of the experience of the other members who took part in the proceedings, so each institution had, in exchange for their own transactions, those of other institutions throughout the world, which were of exceeding interest and value to all their members. He thought that the bond between the various institutions would be rendered closer if they visited each other's districts and held joint meetings; and remarked as a peculiar coincidence that the membership of the North-East Coast Institution was at present exactly the same as that of The Institution of Engineers and Shipbuilders in Scotland.

The Mayor of Hartlepool (Mr. T. Mudd) proposed "Success to the Trade of the North-East Coast." Speaking of the recent engineering dispute, he said that at the beginning of the trouble someone remarked that the employers were in the position of a man who was told by his physician that he must either go through an important surgical operation or succumb. He thought they might to-day feel that the patient had safely passed through the operation, and that the wound was healed. He thought they would agree that the North-East Coast, and more especially the city of Newcastle, should be proud of the great and just and humane Colonel who had done so much to conduct the patient safely through the

operation. He said humane, because he sincerely believed that the charter of freedom which had been established was quite as much a charter of freedom for the worker as it was a charter of freedom for the employer. He coupled with the toast the name of his esteemed friend, Mr. L. W. Adamson.

Mr. L. W. ADAMSON responded. He said that although his knowledge of the trade of the North-East Coast was small as compared with some of those he saw around him, yet, at the same time, he had gone through stern experience. Like others connected with trade, he had seen many ups and downs. He remembered that they were hopelessly beaten in 1872. He had lived to see the climax, he would not say when trade had been victorious, but to a certain extent he had seen the verdict of 1872 reversed. The great difficulty he had found in all matters connected with trade was to make masters and men fully and effectually believe that their interests were common and united. "United they stood, divided they fell." It was the old problem of the "belly and its members." Which was the belly and which the members, he was not going to say. He knew this, that a great many people had not much stomach for the fight when it began, and he thought they had gone through recent experience good naturedly, good temperedly, and with mutual good feeling creditable alike to both parties. It was a difference of opinion which practically had got to such a height that there was nothing for it but to stand to their guns and see what would come of it. It had been an educational process to masters and men, and all must feel that the true way of success for trade was that all should believe in all productive energies being brought to bear to a common end. There was no chance whatever of their being able to maintain their ground against the constant aggressive attitude which trades abroad were adopting, unless they with heart and hand all united to a common end to maintain the supremacy of old England, as being the best manufacturing country in the whole world. He believed they had the men. He knew they had the money; but they might rest quite assured that money would not be embarked in trade in that or any other district in which there was not harmony in all the parties joined together to produce this common end. When he came to that district there was a large glass trade. He was not prepared to say why that trade had failed; but if they asked for the commodities which used to be produced broadcast on that river in the glass line they failed to find any, or scarcely any. The chain trade, of which there were those

about him who knew well that there were eight or ten leading firms on the river, now practically with one exception—the firm he had the honour to represent—was not followed by a single other firm in the district. It was the fact that other people had learned to do the things which they did and do. By science and co-operation they had managed to oust their trade in a great many markets of the world. There was one compensation. They could safely say they had got that new trade, the scientific trade which had cropped up on that river, and which had almost overwhelmed the whole of the other trades of the district. He spoke particularly of the great firm of Armstrong, Whitworth, & Company. He believed he spoke without exaggeration when he said that by their works they practically maintained a population of 100,000 people. This was due, in the first instance, largely to the inventive genius of one or two men, and the world was now covered with their products. He fervently prayed that this great peace which had now fallen to them might be of long continuance. The orders, he hoped, would come back, and once more they might hear the hammers clanging in all the works in the district. His fervent prayer and that of all present should always be, "Give peace in our time, O Lord."

Mr. Robert Thompson (Sunderland) proposed "Our Guests."

The Mayor of Newcastle, in responding, said the prosperity of Newcastle was, in a great degree, dependent upon the prosperity of the engineering and shipbuilding works represented at that gathering, notably with the great works of Armstrong & Co. Its prosperity was also closely identified with the trade of the port of the Tyne. Under the Tyne Improvement Commissioners the river had been made one of the finest and safest ports in the country. During the past year over 13 million tons of coal had been shipped from the Tyne, and the port had been used by vessels representing over eight million register tons. Newcastle Corporation had expended over a quarter of a million in rebuilding the quay wall and other works connected with the port; and if the present trade was to be retained and new trade attracted the Corporation must very quickly enter upon a further large outlay. Efforts were being made by other ports on the East Coast to divert Continental trade from Newcastle and the Tyne, and the latest instance was in connection with the Norwegian trade. It was stated that the Norwegian Commissioners had recommended that the mail service and other trades should be transferred from the Tyne to Grimsby. It was possible that some of the facilities for trade at Grimsby were more modern than on the Tyne, but there could be no question about

the very great advantage which the Tyne held over Grimsby and other ports on the East Coast in being available for large vessels at all hours, independent of the state of the tide. For mail and tourist traffic it was of the utmost importance to be able to advertise a definitely fixed hour of departure all the year round, and that could be done on the Tyne and at Newcastle. In June last year the Quayside Committee of Newcastle Corporation requested Mr. Laws, City Engineer, to report upon the best means of improving the facilities for trade at the quay, and after visiting several Continental ports, Mr. Laws, in October, presented to the committee a report containing proposals which, if carried out, would greatly improve the facilities for trade, and in fact, make the quay in every way admirably suited for the quick dispatch of business. A copy of Mr. Laws's report had been sent to each member of the Council, and if the shipping agents and merchants obtained copies of the report and the plans attached to it, he was sure they would admit that Mr. Laws had dealt with the needs of trade in an admirable way. It only remained for the Quayside Committee to promptly come to a decision upon the report in order that the subject might be submitted to the Council and sanction obtained for carrying out the works.

The PRESIDENT proposed the toast of the "Dinner Committee," and congratulated the members of the committee on the success of the entertainment.

Mr. J. R. FOTHERGILL (Chairman of the Committee) responded. He thanked the members and friends for their support, and expressed a hope that the dinner would now become an annual function of the Institution

The proceedings afterwards terminated.

The following gentlemen were appointed by the Council to carry out the arrangements :—

DINNER COMMITTEE.

Mr. J. R. FOTHERGILL, Chairman.

Mr. ROBERT THOMPSON. Mr. A. G. SCHAEFFER.

Mr. HENRY FOWNES. Mr. JOHN DUCKITT, Secretary.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897–98.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE MARINE SCHOOL, SOUTH SHIELDS, ON FRIDAY EVENING, FEBRUARY 18TH, 1898.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on January 15th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. C. H. Innes and H. E. J. Camps to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Grey, Charles, Mechanical Engineer, 17, Lovaine Crescent, Newcastle-upon-Tyne.

Higgins, C. F., Electrical Engineer, c/o Messrs. T. Richardson & Sons, Ltd., Hartlepool.

Ives, Bernard, Ship Draughtsman, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne.

Jennings, Frederick, Engineer Draughtsman, 54, Second Avenue, Heaton, Newcastle-upon-Tyne.

Jobson, Robert, Jun., Shipbuilder, Clifton Avenue, West Hartlepool.

Macdonald, Charles, Marine Surveyor, 4, St. Nicholas' Buildings, Newcastle-upon-Tyne.

Moorsom, Frederick, Ship Draughtsman, Victoria Road, West Hartlepool.

Morton, David L., Shipbuilder, 126, Aurelian Terrace, South Shields.

Taylor, J. W. H. Maxwell, Engineer Draughtsman, 5, East Parade, Newcastle-upon-Tyne.

Thompson, Charles Henry, Ship Draughtsman, 36, Carlton Street, West Hartlepool.

Thornton, Thomas Lee, Superintendent Marine Engineer, 45, Northcote Street, Newcastle-upon-Tyne.

Trechmann, J. E., Superintendent Marine Engineer, c/o Messrs. Otto Trechmann, Ltd., West Hartlepool.

Wilson, Alfred C., B.Sc., Marine Engine Draughtsman, 1, Bank Terrace, Wallsend-on-Tyne.

Wright, William Charles, Engineer, Sam Sew Rice Mills, Sam Sew, *via* Bangkok, Siam.

GRADUATES TO MEMBERS.

Baker, E. F., Assistant Engineer, H.M.S. "Majestic."

Dobson, Henry James, Shipbuilder, c/o Messrs. William Dobson & Co., Newcastle-upon-Tyne.

ASSOCIATE.

Neilsen, Hans Christian, Shipowner, 12, Cliff Terrace, Hartlepool.

GRADUATES.

Dalziel, E., Apprentice Engineer, 97, Sandyford Road, Newcastle-upon-Tyne.

Fox, Carter, Draughtsman, 7, Coxon Street, Sunderland.

Harden, G. F. St. Clair, Apprentice Engineer, 6, Larkspur Terrace, Jesmond, Newcastle-upon-Tyne.

Hunter, George Ernest, Ship Draughtsman, The Willows, Jesmond, Newcastle-upon-Tyne.

Milne, George Murray, Apprentice Ship Draughtsman, 17, East Percy Street, North Shields.

Nixon, John Robert, Apprentice Engineer, 4, Bath Terrace, Blyth.

Pescod, Joseph Hind, Ship Draughtsman, 1, Railway Street, Jarrow-on-Tyne.

Potts, Joseph, Apprentice Engineer, 14, Moreland Street, West Hartlepool.

Ruhaak, G. H. Müller, Apprentice Engineer, 2, Bolton Terrace, Newcastle-upon-Tyne.

Sanderson, Thomas H., Apprentice Engineering Draughtsman, 31, Park Road, Jarrow-on-Tyne.

Wadd, Herbert W. F., Engineer, 5, Eldon Place, Newcastle-upon-Tyne.

Mr. ARCHIBALD HOGG replied to the discussion on his paper on "The Comparison and Construction of Ships' Lines."

The discussion on Mr. C. H. Innes's paper on "The Centrifugal Pump and Fan" was resumed and closed.

The discussion on Mr. Archibald McGlashan's paper on "Water Ballasting of Steamers" was resumed and closed.

Mr. T. MESSENGER read a paper on "An Instrument for Gauging the Circularity of Boiler Furnaces and Cylinders, and Producing a Diagram."

MR. ARCHIBALD HOGG'S REPLY TO THE DISCUSSION ON HIS PAPER ON "THE COMPARISON AND CONSTRUCTION OF SHIPS' LINES."

Mr. A. Hogg, in reply to the discussion on his paper, said the paper was written to explain a method of comparing the proportions and the construction of the ships' lines. Diagram B (Plate I.) was specially used at the early stage when arranging the dimensions; for this purpose it was sufficient to consider the mean of the ends, because the new ship was based on the performance of known ships, and hence if they got the same mean they could always get the same ends as in the type ship. If the position of centre of buoyancy was written beside the spot "in terms of the length," it would rather complicate the diagram, especially seeing that the figure in many cases would be somewhat similar to that of the draught, which was already noted there, together with the ship's number. It might be better, perhaps, if desired to indicate the ends, to note the figure for correcting the cylindrical coefficient, as this would enable the designer to get the actual block angle of entrance. If separate sheets were used for each type, this would get over any difficulty about the draught: the error in each type was hardly measurable. The speed estimator would find Diagram B of use to tell him at once the best ships to base the new proposal on. Dr. Kirk's block distorted the proportions. Take a full cargo ship of 7 beams having an actual draught of ·48 beams and a mid area coefficient of ·97. The section of this ship would probably have nearly vertical sides and the bottom slightly inclined from the horizontal with a sharp bilge. The nearest rectangle which would approach this form and enclose the same area was one having the same breadth but a lesser depth, as was done by the new block, which in the above case would show a ship of 7 beams having a draught of ·466 beam, Dr. Kirk's block would indicate a ship of 7·22 beams and a draught of ·48 beam. If the coefficient had been ·8, the vessel's side, being vertical, the proposed block would represent a ship of 7 beams and draught of ·384 beam, while Dr. Kirk's would show one of 8·75 beams and draught of ·48 beam. The important point was the proportion of mean beam to length. The wet surface was not taken from the new block suggested by the writer, but from a diagram of curves, as was explained in the paper. The angle of entrance was taken in "beams," as this gave the best idea of fineness, a full ship's entrance might be one, while that of a fine ship might be

three or four beams. When arranging the proportions of a ship, the block used should represent the ship as it was over the curved surface, or lines proper, when they used the perpendicular length, as in the case of a warship, they were looking at the length of entrance as being, say, $2\frac{3}{4}$ beams, when in reality it would probably be $3\frac{1}{4}$ beams, and thus they might easily say two ships were different, when they were in reality alike. He had prepared a sketch (Diagram H, Plate XV.) with the fore body stations for two vessels, like those on Diagram C (Plate II.). Both were drawn on the same basis. It would be seen that the difference was such as was indicated by Diagram C. The displacement was distributed, vertically, in such a way as to make the ship narrower and deeper all fore and aft. Thus, to make a block represent the ship shown in dotted lines, the block beam must be something less than the breadth of the ship on L.W.L. If the draught and mid area were alike, it did not follow that the mean beam must be also alike; if it were so, then a triangular section would have equal value with a rectangular one. Regarding the area curve, the writer remarked that all vessels ought to have the same character of curve, etc. This curve "must" be a hollow one in a vessel having the lowest possible cylindrical coefficient, but it could be either hollow, straight or round in the fuller ships; between these extremes the curves ought to graduate from the hollow, straight or round in the full ships, to the hollow in the finer ships. Unless the area curve was specially drawn they had no guarantee that they were following the same character of curve. For this reason it was good to have ready a standard set of approved curves. Any standard was of use if it gave a curve enclosing the required area, which could be modified to the same extent for every ship. The offsets in the tables were given so that this could be quickly done and easily measured at any part of the curve. The writer had carefully examined the curves shown by Mr. Robert Thompson, and thought that they bore out what was said in the paper. The four curves were drawn on Diagram M (Plate XV.), having a common end and centre line. The No. 4 curves were drawn in Diagram K (Plate XV.), placed so that the shoulders of the curves occupied the same line. The extreme ends of the No. 1 curves were drawn in Diagram L (Plate XV.). The writer's curves were designed to give what he considered the limit fineness of ends and fulness of midship body; many ships, of most types, had been built from these curves, and had been shapely and successful in every way. Every ship had a fair area curve, which curve was the basis of the whole design; but it was not the general practice to start the lines by considering directly the area curve, any system which did so must

be applicable to all designs. Some experience was required to thoroughly understand the ship's lines under any circumstances, but having the area curve, it became a comparatively easy task to sketch the stations. The advantage of using tracing paper to check the areas was, that at the first trial, if the two parts did not agree, the difference was easily seen, and assisted in resketching the station. A draughtsman could sketch one in a few minutes—say three—and it would take about half an hour to sketch all the stations in the body plan. Of course, a line plan, drawn by an inexperienced man, would have defects which would not be there if drawn by an experienced man. The proportions of entrance and run, and the character of curve, should be considered whilst designing the sectional area or mean water-line curve. It was an advantage to know that when this one curve was drawn the basis of the lines was designed, and that when the line plan was finished they were bound to have the required displacement and centre of buoyancy. Regarding the midarea coefficient, the writer used a certain coefficient for each ship; but it might sometimes have to be modified to suit Lloyd's grade, no matter what system was used, this ought to be looked to. He (Mr. Hogg) would again draw attention to the block coefficient. To guess what this might be from looking at a ship was by no means reliable. The fore end might be fuller than the aft; it might be ·82 forward and ·77 aft; besides, V-shaped stations always made the model look as having a finer coefficient than it had. In comparing models, the water-line of a beamy ship having a small coefficient would look as fine as that of a narrower ship having the same coefficient, while in reality the one might be 20 degrees and the other as low as 15 degrees. In conclusion, the writer wished to thank those gentlemen who had so kindly discussed and criticised this method of treating an old subject.

The PRESIDENT said it would be their pleasure to convey to Mr. Hogg the thanks of the meeting for this very interesting paper, which, he was sure, they would all find of very great use.

This was accorded by acclamation.

ADJOURNED DISCUSSION ON MR. C. H. INNES'S PAPER ON "THE CENTRIFUGAL PUMP AND FAN."

Mr. T. POLLARD, in concluding the discussion on Mr. Innes's paper, said the paper was really too good for discussion, and Mr. Innes was the only authority upon the subject. He should like to know, however, whether the given formulæ relative to pipe bends on pages 45 and 46 could be relied upon. He should say they could not with any degree of accuracy. He should also like to know the best curve for the fan. All the makers said theirs was the best—and they appeared to use the same curve for pump case; but the only way to decide would be to test each impeller with the same engine, and see which gave the greatest discharge with the same I.H.P. or relative to I.H.P. Again, in designing the pump case, instead of making the perfect spiral, the metal should be set back when approaching the discharge orifice to avoid vibration, otherwise the water being discharged so near the impeller is throttled, and tends to set up vibration in the pump and loss of power.

Mr. C. H. INNES, replying to the discussion, said in regard to what Mr. Duncan had said in the first trial of the Tangye pump, the weight of water was assumed to be 62½ lbs. per cubic foot, but as the weight of a cubic foot of salt water is 64 lbs., the difference is only 2 per cent., and as the efficiencies are all less than 50 per cent. it would affect these 1 per cent. A second trial was made on January 15th,* and as, unfortunately, the sample of the fluid that passed through the pump did not reach the Rutherford College owing to an accident, the density was taken as 64, so that every allowance might be made for the pump. The calculations were not made for the pump alone, but for the pump and piping. In the second trial, a glass pipe was placed on the discharge pipe, but the tide soon fell below its level, so that it was of no service. The reason for making the second experiment was that it was discovered after the trial that the pump had been started without the ejector having been used; as he (Mr. Innes) was not in the engine room at the start he naturally concluded that it had been used, until it became necessary, after Mr. Duncan's question, to enquire into the matter. There was, therefore, probably a

* See Table XII., page 136.

TABLE XII.—TRIAL OF A TANGYE CENTRIFUGAL PUMP AT THE WALLSEND SLIPWAY, JANUARY 15TH, 1898.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
1. Fall of water inside dock in feet	21 0½	20 9	20 2	19 9	19 6	19 1	18 10	18 4	18 1	17 8	17 5	17 1	16 8	16 3	15 11	15 6	15 5	15 2	14 11	14 9
2. Head outside dock	19 0	18 0	17 0	16 10	15 0	14 0	13 0	12 0	11 0	10 0	9 0	8 0	7 0	6 0	5 0	4 0	3 0	2 0	1 0	—
3. Head inside dock at end of interval																				
4. Boiler pressure	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
5. Interval in minutes and seconds	—	11·45	11·45	11·0	10·30	9·30	9·15	9·15	9·0	9·0	9·0	8·30	8·30	8·15	8·45	8·40	8·20	8·0	7·40	7·20
6. Mean head in feet	—	2·395	2·957	3·457	4·125	4·791	5·457	6·083	6·707	7·375	8·041	8·75	9·375	9·9575	10·582	11·375	11·9575	12·792	13·546	14·33
7. I.H.P.	—	83·75	81 4	105·1	123·6	144·35	150·5	176·0	188·0	188·25	217·0	254·9	262·6	270·3	276·0	277·3	274·1	288·0	289·2	285·0
8. W.H.P.*	—	16·3	19·7	24·66	30·7	37·9	44·4	49·9	54·1	59·6	65·0	74·25	79·6	87·25	85·25	92·4	98·0	105·5	117·5	120·5
9. F.H.P.	—	7·06	7·08	7·5	8·26	8·76	9·1	9·4	9·72	10·0	10·4	11·74	13·13	13·76	14·0	14·92	15·1	15·35	15·6	16·0
10. S.H.P.	—	76·69	74·32	97·5	115·34	135·59	141·4	166·6	178·28	178·25	206·6	243·16	249·47	256·54	262·0	262·38	259·0	272·65	273·6	269·0
11. Hydraulic efficiency, per cent., η	—	21·3	26·5	25·3	26·7	28·0	31·5	30·0	30·3	33·5	31·5	30·5	31·9	34·0	32·6	35·1	37·9	38·8	43·0	44·8
12. Calculated efficiency, per cent., ηc	—	22·5	25·1	26·4	27·3	27·9	29·55	30·6	32·0	33·2	33·6	29·9	33·9	34·8	35·6	37·3	38·5	39·4	41·1	42·0
13. $\eta - \eta c$	—	−1·2	+0·4	+1·1	−0·6	+0·1	+1·95	−0·6	−1·7	+0·3	−2·1	+0·6	−2·0	−0·8	−3·0	−2·2	−0·6	−0·6	+1·9	+2·8
14. Revolutions per minute	—	97·1	98·3	103·5	113·3	120·4	124·8	128·0	132·5	135·7	140·1	145·5	150·2	152·0	154·0	156·3	157·8	158·1	158·4	159·3
15. Velocity of discharge from pump	—	8·25	8·1	8·65	9·075	9·63	9·9	9·86	9·83	9·83	9·83	10·35	10·35	10·65	9·8	9·85	9·95	10·1	10·1	10·26
16. Orifice $\frac{Q}{\sqrt{gH}}$ in square feet ..	—	6·65	5·85	5·82	5·55	5·475	5·26	4·99	4·72	4·50	4·32	4·36	4·21	4·2	3·77	3·64	3·57	3·52	3·4	3·38
17. Time in hours and minutes ..	9 41½	9 53¼	10 5	10 16	10 26½	10 36	10 45¼	10 54½	11 3½	11 12¼	11 21½	11 30	11 38½	11 46¾	11 55½	12·4⅛	12 12½	12 20½	12 28⅛	12 35½
18. Quantity discharged during interval in cubic feet †	—	41,209	40 428	40,408	40,383	38,784	38,761	38,738	37,525	37,503	37,480	37,280	37,255	37,234	36,341	36,218	35,095	34,278	33,698	31,900

* In the above the weight of water per cubic feet is taken as 64 lbs.

† This does not include leakage, which at the end of the trial was found to be 30·6 cubic feet per minute, and was probably less during the remainder of the trial.

little air in the pipe, but as a cock had been placed on the discharge pipe, and, as this had been opened before the trial, the quantity was not large. This air would not, under these circumstances, affect the theory of the subject, as it would by the centrifugal force of the water be driven into the discharge pipe, and merely reduce the efficiency by increasing its resistance. In the second trial, not the smallest quantity of air could remain in the discharge pipe or pump, as the cock to which the glass tube was fitted was kept open as long as the glass tube contained any water, and the ejector was also used, although there was under the circumstances no necessity for so doing. The friction of the engine was taken by running the engine unloaded at speeds varying between 122 and 185 revolutions. This slightly under-estimated the friction, but not to any very great extent. As an example of this take Mr. Weighton's trials of the quadruple expansion experimental engine, at The Durham College of Science. Here the difference between I.H.P. and B.H.P. at full load was—

$$188{\cdot}45 - 168{\cdot}93 = 19{\cdot}52,$$

and when the I.H.P. was reduced to 59·74, the loss was—

$$59{\cdot}74 - 44{\cdot}56 = 15{\cdot}18.$$

The diagrams of B.H.P. and I.H.P. show that they were connected by a linear equation, which is—

$$\text{B.H.P.} = {\cdot}964\ \text{I.H.P.} - 13{\cdot}2,$$

so that the I.H.P. of the engines when running light would be 13·7, and this divided by the F.H.P. at full load is ·71. However, to be on the safe side, a fresh series of efficiency calculations have been made for the first trial, and in these it is assumed that the weight per cubic foot was 64, that the head was under-estimated by 6 inches—a manifest impossibility—and the friction half as much again. The efficiency in no case is increased by more than 3 per cent. The engines and pumps were set in line about two years before the experiment. The head was measured on the two dock scales, outside and inside the gates which measure feet above the sill, and in addition a pole on the end of which 12 inches were painted in alternate white and black bands was held by an assistant against the outer post, so that inches could be accurately measured. The motion inside the dock was absolutely nothing, and so smooth was the water that the figures on the scale were reflected. On the outside, on March 13th, the motion of the water was never more than 4 inches, and on January 15th about 2 inches. On the former occasion there was a light air from the other side of the river, and on the latter what little air there was, was down stream. In the first trial the leakage was not

measured, as there was absolutely no necessity to do so. Great care was taken in closing the gates on both occasions to minimise leakage, which, if anything, was a little larger on the second occasion than on the first. On January 15th it was measured in the following manner :—There are four channels running parallel to the keel blocks and on either side of them, meeting in a transverse channel which leads to the pumps. In each of these four, three experiments were made, and the highest results used for calculation, because the object was to show how exceedingly small was the leakage and to place beyond doubt the statement that he had already made that the leakage could be neglected in comparison with the large volumes pumped; it amounted to a shade more than half a cubic foot per second, which compared with 30,000 in eight minutes is less than 1 per cent. The experiments were made thus: a small piece of wood was timed between two points 12 feet apart; it was, of course, given a flying start, and in each case it kept in mid stream; the depth and breadth of the water was taken at three points in the 12 feet, the depth being taken at the middle of each section. The following table gives the figures of the best of the three experiments in each case :—

LEAKAGE EXPERIMENTS, JANUARY 15TH, 1898.

Mean Breadth of Channel. Inches.	Depth. Inch.	Velocity per Second in Feet.	Cubic Feet per Second.
18⅞	⅝	2	9·85
18	½	1·71	6·4
18½	½	1·5	8·32
19¼	½	1·5	6·03

This amounts to 30·6 cubic feet per minute.

In the calculation of the theoretical efficiency η_c in the second trial on January 15th (see Table XII.), the part of the loss of head due to the square of the velocity was found by multiplying that square by ·056 instead of ·07 in the calculations for the first trial. This slightly lower value being due to the absence of air in the pipe.

In reply to Mr. Pollard, none of the formulæ for surface friction of piping can be relied on, because the condition of the surface may vary considerably, but there was very little doubt that water friction varied as the square of the velocity, and that was all that was assumed in the calculations on the Wallsend trials. There were many curves for the vanes of the fan, which would give excellent results, because so long as there was no sudden change of velocity, and direction of motion no loss of energy would take place. In a pump, any vane whose discharge angle ϕ lay between 15 degs. and 90 degs. should give good results if inflow

took place without shock, and the curvature of the vane was not too sharp at any point, always provided that the volute and diffuser were properly proportioned.

In a fan a forward direction at discharge was advantageous because a high manometric power was obtained; also the peculiar construction of the Rateau vanes was advantageous, because the air was taken round the bend from the eye to discharge, whereas in most fans it had to get round this corner as best it could. The method of constructing these vanes, which had already been described, could be modified to suit any angles of inflow and outflow, and this would without doubt give the best form of vane. The most conclusive method of testing the relative efficiencies of fans or pumps would be to drive them in turn by an engine, whose friction at any power or speed was known. Each should be made to work at the orifice for which it was designed, and the ratio of useful horse-power to shaft horse-power would give their relative values.

In designing the pump case he (Mr. Innes) could not agree with Mr. Pollard that the metal should be set back at the commencement of the spiral of the volute, but the tongue of metal crossing the diffuser in Fig. 1 (Plate VII.) would be better omitted, as it would produce eddies and loss of power.

The PRESIDENT asked those present to authorise him to convey to Mr. Innes their hearty thanks for his highly scientific paper, which must have cost him an immense deal of time and thought to get together. He was sure they were all very greatly obliged to him for enabling them to put this upon the records of the Institution.

This proposal was adopted by acclamation.

ADJOURNED DISCUSSION ON MR. ARCHIBALD McGLASHAN'S PAPER ON "WATER BALLASTING OF STEAMERS.

Mr. R. H. MUIR thought Mr. McGlashan well deserved the thanks of the Institution for his paper. It was useful and thoroughly practical. The idea of fitting side tanks or inner skin into a steamer was, of course, nothing new in Admiralty work; but he dared say it was quite new in ordinary cargo steamers. Of course, tanks had been fitted into the sides of steamers for carrying oil fuel, and they had the feeling that when full it eased the roll of ships and helped them in many ways. Mr. McGlashan began his paper by summarising the difficulties to be got over in ordinary cargo steamers in ballast trim, and they could not minimise their importance. Previous speakers had referred to these at the last meeting in West Hartlepool, and he need not recapitulate except to mention a coincidence, the question now being discussed by this technical Institution had been brought before the notice of the House of Lords by a noble lord pointing out the serious dangers vessels of this class were liable to and moving a resolution, "That an instruction be issued to the surveyors of the Board of Trade authorising them to detain any vessel leaving a British port, unless her propeller was two-thirds immersed." Nothing definite resulted, still it went to show the subject was having consideration in many quarters. A good deal had been said about the difficulties there were in fitting these tanks, and it was surrounded with details; but surely there was enough of ingenuity in shipbuilders and engineers to get over these. The most important point was the depth of tank from ship's side. He would make it as deep as possible, in a ship of the dimensions given, viz., 51 feet beam, say 3 feet, and make the inner skin a vertical line from deck to tank top. The reduction of capacity may be more apparent than real, still it may be admitted for some cargoes it would be a deduction, that was the commercial question. Well, "you cannot eat your cake and have it too." Against the loss of cargo space they were getting improved construction of the steamer, they were getting an easy roll, they were getting the centre of gravity higher, they were getting the propeller immersed, and in every way benefiting the vessel, so that he thought the idea of fitting these side tanks would be a thing of the future. There were other points Mr. McGlashan referred to, such as the fitting of deck tanks. He (Mr. Muir) thought in fitting deck tanks they did a great service to the steamer in

lifting the weight as far as possible, and in ordinary cargo steamers if they could fit some 30 or 40 tons of fresh water on the top deck by extending the engine and boiler casings a few feet at each end, usually they had plenty of space to do it, it would be found very convenient, besides increasing the hold capacity. These tanks were built especially in cattle carrying boats. They could be kept filled by filtering water from the sea. Another idea was to lengthen the hatch coamings on the top deck over the deck plating. On several ships built recently under his own supervision they had increased the coamings considerably beyond the ends of the hatchway. These spaces formed stores for cargo chains, etc., thus collecting heavy weights in suitable places; a like arrangement might be made to carry water. These were only some ideas that might be improved upon. He welcomed the paper, and had great pleasure in adding his testimony to its great value.

Mr. J. T. Batey thought the paper read by Mr. McGlashan at their last meeting in Hartlepool, was certainly one that treated upon a subject which was at the present time occupying the minds of shipowners, underwriters, shipbuilders, and engineers. The shipowner found that he was often compelled to send his vessel across the ocean in ballast in order to secure a cargo, and very often he had to send his vessel from a discharging port to a loading port, and, as frequently happened, in making the change of ports, say, from the Continent to the Bristol Channel or the North-East Coast ports, the vessels were delayed by stormy weather, against which the ships could not make headway, owing to their being so lightly immersed in the water, and having such a large proportion of the hull exposed to the wind. In consequence, vessels were delayed which, of course, was a source of loss to the owner, and the broad, shallow draught steamers which were being built at the present time would, he was afraid, prove to be a source of trouble in this respect, unless they could arrange to have a sufficient quantity of water ballast arranged in them to sufficiently immerse their hulls to enable them to make a passage in bad weather. Apart from the question of passage making, they had the very serious question of the failures in the tail end shafts, by which valuable property and human lives were placed in perilous positions, and not unfrequently both had been lost. Consequently, one of the chief questions which they, as shipbuilders, had to face was to find a means whereby a shipowner might be able to send his vessel to sea in ballast when no cargo offered, and that with every prospect of making a passage. Of course this could be done in a variety of ways, but it must be done at

the minimum cost with the maximum efficiency, otherwise the extra first cost of the steamer might be so great as to completely dispel any hope of keeping up the already small return upon his capital. Mr. McGlashan brought forward, to meet this case, a vessel constructed with side tanks, and which he contended would supply what was required. He quite agreed with him that the quantity of ballast was supplied, and placed in an exceedingly good position to secure good sea-going qualities, but he was inclined to think that when the shipowner came to consider what he had to sacrifice in order to obtain this extra ballast that the said sacrifices would outweigh the benefits. In the first place, they had decreased capacity in the holds of about 12,600 cubic feet, or 280 tons at 45 cubic feet per ton; this was a large loss when carrying light bulk cargo; however, against this they had a decreased gross tonnage of about 170 tons, and a decreased net tonnage of about 116 tons, always taking for granted that the machinery space was large enough to secure the 32 per cent. of the gross reduction. On the other hand, if the weight of the vessel was not more than a vessel built in the ordinary way, the deadweight carrying capacity remained the same, and the shipowner reaped the benefit of the reduced tonnage as before stated, so that if it was advantageous for one cargo it would be the reverse in another case. This was a matter which the shipowner must decide to suit his own requirements. The next important matter which struck one as being disadvantageous to the side tank steamer was that he was afraid that the first cost would be considerably increased. Mr. McGlashan was good enough to inform them that the space between the inner and outer skins was 2 feet 5 inches. Now, arrange this as they liked, the space was very confined, and, depend upon it, they would have to pay their workmen higher rates who had to work in these confined spaces. Besides, the workmanship must be of the very best in the tanks, as, when the side tanks were full, there would be a constant heavy pressure upon the plating near the bilge and tank side of the double bottom, and to obtain this high standard in the confined space would require great care, and would take up a great deal more time than ordinary work, where the space was not so confined. Then again, they had the testing of these tanks, which would require to be carefully carried out, and upon which a good deal of time would be expended owing to their being so difficult of access. This was not a large item, but it was astonishing how the cost mounted up when such work had to be done. Another item which would add to the cost was the making of water tight compartments in the double skin in order to make the connections to the sea for the requirements of the machinery, and he supposed that wells

would have to be constructed in each hold for drainage purposes. Add to this the cost of piping and pumps for filling and emptying the side tanks, and it appeared to him that the cost added to the vessel would be considerable when built with side tanks. There was no doubt the vessel would be better able to make a voyage in bad weather, and it remained with the shipowner to weigh up the advantages and disadvantages which they put before them, and decide whether he would secure a return upon the extra expenditure which, in his humble opinion, would be incurred in building a vessel with side tanks. The assumption of Mr. McGlashan that the safety of the vessel would be increased was one with which he heartily concurred; they had had cases where a vessel had been saved from total loss by the inner bottom remaining intact when the outer skin was pierced, and, without doubt, the inner skin of the side tanks would answer a similar purpose should occasion require it. But in the event of damage to the side tanks, would the cost of repairing them not be considerably more than for repairing the ordinary shell in a vessel built in the ordinary manner? Without doubt, such would be the case; but the question was, would not the extra safety outweigh the extra cost of repairs? He took it that by adopting side tanks an increased ballast capacity of about 730 tons was obtained over the cellular double bottom. Now, if a deep tank about 40 feet long was to be constructed immediately in front of the stokehold bulkhead, and carried up to the height of the lower stringer, they would obtain a tank having a capacity of about 930 tons, or 200 tons in excess of the vessel with side tanks. A suitable hatch with a winch could be arranged upon the bridge deck immediately over the hatches leading into the deep tank, so that the cargo in this part could be manipulated with ease and rapidity. The bulkhead in the forehold could be placed so as to form the fore end of the deep tank, and thus leave a roomy forehold, which would be most valuable and easily worked—which would counterbalance the little extra trouble required to work cargo out of the deep tank hold. Now, this deep tank hold would not increase the first cost nearly so much as the side tanks, neither would there be a loss of capacity due to side tanks; they would have a greater immersion due to the extra ballast, and the cost of repairs would not be increased as in the side tank arrangement. One thing might cause inconvenience, and that would be the trim of the vessel; but, with a little manipulation, he thought this might be satisfactorily arranged, even suppose they sacrificed a little ballast in the tank in the forehold. Such a deep tank, having a capacity of 920 tons, might be considered too large; but they had recently built vessels with deep tanks holding 820 tons, and they had

given so far every satisfaction. The subject of water ballasting was so interesting, and at the present time was attracting so much attention, that one could go on bringing forward endless points of interest if time would allow, and he thought they were deeply indebted to Mr. McGlashan for giving them this opportunity of ventilating the question.

Mr. M. C. JAMES observed that the former speakers had, to a large extent, said what he had in his mind; but there were still one or two other points to which he should like to draw attention. In the first half of Mr. McGlashan's paper, where he detailed the various developments which had led up to the present unsatisfactory condition of things as regarded the ballasting of the modern huge, full-bodied, flat-bottomed cargo ships now employed in the North Atlantic trade, he remarked that "the proportion of beam to draught of water had considerably increased of late," and then showed very clearly how this, to a large extent, affected the lightness of draught. He (Mr. James) thought the vessel, whose particulars Mr. McGlashan gave in the table appended to his paper, under the letter H, must surely have been specially put forward as a "fearful example," her dimensions being, length 338 feet by 51 feet beam. Now, if any shipbuilder had proposed a beam of that sort fifteen or twenty years ago, he would have been looked upon as being about as mad as a shipowner who would propose to send his ship across the North Atlantic in mid-winter in ballast trim. If this rushing to extremes went on in the proportions of beam to draught, there was no possible arrangement of ballast that would keep pace with it. Further on in his paper, Mr. McGlashan spoke of the main purposes of ballasting steamers being to increase the draught so as to make them manageable in rough seas by immersing the propeller sufficiently. He (Mr. James) thought in the anxiety to get the propeller covered, there was a tendency to lose sight of the fore end altogether. It was too often thought to be quite sufficient if the propeller was immersed, but the lightly immersed fore end made the vessel almost unmanageable and rendered it very difficult indeed to keep on a steady course. Speaking of deep tanks: such a tank as Mr. Batey had suggested had been fitted in a steamer he had had to do with; but he (Mr. James) could not say he admired them or that they afforded a satisfactory solution of the difficulty. He shared Mr. McGlashan's objection to deep tanks, they were very objectionable in many ways. In some recent vessels deep tanks had been fitted immediately abaft the engine space: in such cases there was the thrust recess and shaft tunnel to make watertight, so that on the whole it was a very unsatisfactory and costly

job; but he thought Mr. McGlashan's side tanks would be almost, if not quite, as objectionable as deep tanks. How did he propose to sound them? He (Mr. James) did not see how the pipes could be led straight down to these tanks. Then, again, these deep side tanks could not be filled entirely by gravitation, they would have to be pumped up, and he took it there would have to be a more or less elaborate arrangement of pipes and valves connected to the various tanks and wells. There would, he considered, be considerable danger when the vessel was bunkering under tips with a little carelessness on board. Perhaps, as often happened, the senior officers and engineers on shore at the shipping office, and a junior engineer or even the donkeyman in charge, what would happen if any little bungling took place in working the various valves if water ballast was being put in or removed from these deep side tanks, he did not like to think. The question of cost had been touched upon, he thought that a grave objection to this system of construction, also the inaccessibility of these tanks for examination, and this, he thought, would add a new terror to surveyors and those who had to crawl through tanks and boilers, because the ship's sides would be divided into three longitudinal cellular spaces, the manholes would be very small through the stringers, and the tendency, he feared, would be for those spaces to be more or less neglected; moreover, the upper part, between wind and water, would be very liable to excessive corrosion, especially in the case of a steel vessel, and he would not be surprised to find it wasted away to an alarming extent in three or four years. Another point that occurred to him was, that if the tanks were carried right up to the deck as proposed, unless special means were taken in the upper works, they would probably develop signs of weakness. He supposed the frames would be cut and kneed on to the top part or stringer over the side tank; if so, the tendency would be to produce such straining and defects as were found in the 'tween decks of the early oil steamers. One advantage of carrying water ballast in these side tanks would be not so much in raising the centre of gravity, but in what was technically known as "wringing out the weights": this increased the length of the vessel's radius of gyration, and so counteracted the unavoidably excessive metacentric height in the ballast trim, thereby diminishing the period of roll and improving the behaviour of the ship at sea in ballast trim. However, all things considered, he (Mr. James) would prefer Mr. Maxwell Hill's system of fitting tanks for water ballast on deck incorporated with the vessel's structure. He knew people connected with the working of vessels with ballast tanks constructed on Mr. Hill's plan, and they spoke very highly of the ship's behaviour in ballast trim.

The SECRETARY read the following communication from Mr. J. King:—

DEAR MR. DUCKITT,

As I am unable to be present at the meeting of the Institution on Friday, I send you the following remarks on the very able paper by Mr. McGlashan on "Water Ballasting of Steamers." The side ballast tank as described is a new feature on a subject of great importance. It seems to me that the adoption of side tanks would involve some additional structural weight. The plating of the wing tanks, especially near the bottom, would require to be of sufficient thickness and sufficiently well stiffened to sustain the considerable head of water in the tank; and although some saving of weight may be obtained by a possible reduction in the scantlings of the ship on the ground of the strengthening effect of the inner plating and its framing, that saving, I think, would not be enough to cover the extra weight required for the proper construction of the tanks.

The tanks would be somewhat difficult of access for cleaning and repair, and the checking of corrosion would be rendered less easy. The inside plating being in direct contact with the cargo would be, with certain cargoes carried in rough weather, liable to damage. The longitudinal stiffening effect of the side tanks would greatly assist the structure in longitudinal stresses, and would therefore be of great value, but that stiffness would require to be gradually reduced at the tank ends to prevent such a sudden termination of strength as would develop local weakness. Diagram 8 (Plate XIV.) does not show very clearly whether the side tank and double bottom form one water space or not, but I take it that each will be a separate compartment. In that case, I think that whether the double bottom is full or not, there would be such a considerable force brought to bear on the margin plate due to the vertical momentum of the side ballast when the vessel is rolling heavily, as would be severely felt by the connections, and special care would be required in arranging the support for the margin plate, although the rolling of a vessel with side tanks full would probably not be so violent as in a vessel without such an arrangement for carrying the ballast weights high in the section.

The experience that will be gained by the vessel now being built on the side tank system will be very interesting and valuable, and I hope Mr. McGlashan will supplement his paper by giving the Institution some information as to how this important development turns out.

Yours faithfully, J. KING.

MR. A. McGLASHAN'S REPLY.

Mr. A. McGlashan, replying to the discussion, said to do full justice to the important discussion which had taken place would require a lengthy reply. He would endeavour, however, to be as brief as was consistent with fairly facing such objections as had been made to the proposals contained in the paper, including the remarks made that evening. Little or no notice had been taken of the major portion of the paper, in which attention was drawn to the striking changes that had taken place in modern steamers requiring them to have increased water ballast capacity, and the inadequacy of the provision made for carrying it. The case for increased water ballast capacity was, therefore, tacitly admitted to have been made out.

He was sure the Institution owed thanks, and personally he did, to Mr. Fothergill and Mr. Hirst for giving them the benefit of their sea experience, as well as of their wide general knowledge as to the mischief arising from deficient ballasting, particularly with regard to the machinery; and their appeal for more ballast should not be without good effect.

Mr. Robert Thompson's appreciative criticism was particularly valuable because of his extensive experience both as shipbuilder, shipowner, and repairer. He frankly acknowledged the need for more ballast, and to some of his other remarks he had the pleasure of partly replying at the previous meeting.

Mr. Yeoman did not hesitate to confess that more ballast was wanted in modern steamers. As an expert in analysing the life loss returns, as well as a shipowner, he called for a ship capable of doing its work under all conditions, and in such a way as would give the sailor no undue anxiety; and in this he was sure he would be backed up by the sentiment of the members of this Institution.

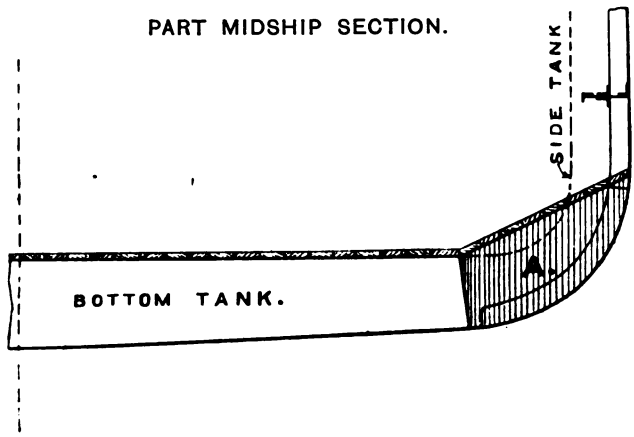
Mr. Arnison was undoubtedly correct in his opinion as to the increased longitudinal strength of the side tank system. But at the same time care had been taken to increase the transverse strength by very efficient web frames within the side tanks, and so far from there being, as Mr. A. E. Muir feared, any loss of transverse strength there would be a great addition to it by the inner bottom and side tank plating forming a continuous connection round the bilges where the effects of transverse weakness were frequently visible in large ships.

The reception given by the President to the paper, and to the proposals it contained, was at once generous and discerning, and the writer could not wish for more valuable testimony to the practicability of the side tank system, and to some of the advantages it offered than he gave in his contribution to the discussion ; while his answers to some of the objections of previous speakers were sufficient to warrant him in not giving a further reply to these objections. And though he favoured hold compartments being constructed and used for water ballasting more than was done in the paper, he was as emphatic as anyone as to the need of more efficient ballasting than often obtained in modern cargo steamers.

In reply to Mr. De Rusett, he might say that in carrying out the arrangement illustrated in Fig. 9 (Plate IX.) the side tanks on each side of the ship would consist of three separate compartments, above and independent of the bottom tanks, and they would be filled and emptied through pipes fitted direct to each compartment. Wells would be formed in each bilge at the after end of the midship holds and engine room, so that any water which found its way into these compartments might collect in them and be pumped out by steam, or hand pumps, as occasion arose. As to the thickness of the shell there need be no misgiving, as strakes of normal thickness were not reduced. Of course doubling strakes, and such like plasters, required on ordinary steamers were fully compensated for by the side tanks. The formation of the valve recesses would not be costly, being definitely arranged for from the first. They required no extra material in their formation, and though they required a little extra riveting and caulking no work need be done twice over in connection with them. It was not expected that the side tank plating would collect so much sweat from cargo as the sides of an ordinary ship did, and as water could not enter the holds in case of a slight straining of the outer shell there seemed to be no call for cargo battens ; but if these were desired they could easily be fitted. He could not enlarge the scope of the paper by entering into the relative capacities of the ships given in the table. They were ships of different types and sizes and age. He had not the revised tonnages of some of them, if, indeed, they had been revised according to the late regulations, and it seemed to him that introducing the tonnages and capacities of them would only lead to confusion. There had been an attempt on the part of one or two speakers, however, to make a great deal of the reduction in measurement capacity, and with that he might be able to deal without going into the general question of tonnage and capacity.

With regard to Mr. Sivewright's observations, he might say, 1st, that the mistake had not been made of making the side tanker fit only for a particular trade. She would be very suitable for general trading, and would be as good a ship as any other for carrying cargoes both ways when they could be found. But she would have the additional advantage of being equipped with water ballast to go without cargo from places where none were to be found to where they were; and that was something for which many shipowners were willing to pay a little. 2nd, deadweight was still the principal standard of a steamer's earning power. This was proved in several ways; for instance, owners had readily spent large sums strengthening their ships so as to get a few inches more loading, although in doing so they did not add a cubic foot to the measurement capacity. And on every hand there was heard the complaint that ships paid better under a foreign flag because they were allowed to load deeper than under the British flag. Again, in many hundreds of enquiries for steamers which he had seen, deadweight capacity was given as a condition to be fulfilled, while comparatively few, except for special purposes, required a given cubic capacity as a condition of contract. He was far from seeking to ignore the value of cubic capacity, however, and would look, in the 3rd place, at the rough estimate of applying the side tanks to a vessel 315 feet by 42 feet 6 inches by 26 feet 3 inches, with which they were favoured. The decrease of net tonnage was given as 70 tons. This was equal to a decrease of 103 tons gross, which was equal to 10,300 cubic feet of space clear of ceiling and cargo battens. But by the operation of the rule which required 13 per cent. of the gross tonnage to be set aside for propelling power space in order that 32 per cent. might be got off the gross tonnage, 13 per cent. of 10,300 cubic feet, or 1,339 cubic feet of this reverted to the bunker space, bringing down the net reduction of capacity to 8,961 cubic feet, which was the only really valuable space shut out by this simple application of the side tanks. Of course he might add to this the space between the frames, which is worthless for carrying bales of wool, or cotton, or for timber and such like light cargoes, but which many include in the measurements, so as to swell the figures of the cubic capacity. So let them see what this might amount to. Length of tank, as given, 173 feet × depth of side from finish of ceiling, say 21 feet × breadth of space from shell to face of cargo battens — 9 inches × 2 sides of ship = 5,449 cubic feet + 8,961 already deducted = a total of 14,410 cubic feet, *including bunkers*, even if this very unfair method of treatment was admitted. They were told, however, that the reduction worked out 14,056 cubic feet of hold capacity

+ 100 tons of bunkers, which, at 45 cubic feet per ton = 4,500 cubic feet = a total of 18,556 cubic feet, which is 4,146 cubic feet more than it worked out. They were told that it was a rough estimate, but it seemed too rough for any useful purpose. He might be allowed to point out that in many large steamers thousands of cubic feet in the bilges (shown at A on the accompanying diagram) were lost for carrying either ballast or cargo. In the side tanks they were of course available for water ballast, and it looked as if this space had been included in getting up the 18,556 cubic feet, which, of course, would be a mistake. But so far from the side tanker having a loss of cubic capacity, she had abso-



lutely as much bale capacity for a vessel of her size than if she had been built in the ordinary way without side tanks, but with a lower deck. 4th, when they were told that with large steamers there was no difficulty in getting well on to 1,000 tons of water ballast, and that this had been augmented by carrying ballast in the tunnel, he wondered how he had often found great difficulty in finding capacity for so much. Looking up Lloyd's Register, he found among many examples of what was actually attained in this direction the following most modern vessels, which Mr. Sivewright might perhaps recognise, and which might be taken as fairly large vessels compared with those in the Appendix table of the paper, viz. :—

Length.		Breadth. Ft. Ins.		Depth Moulded. Ft. Ins.	Gross Tonnage.	Water Ballast. Bottom. Tons.	After Peak. Tons.
330	×	43 1	×	22 3	3,345	547	24
331	×	42 0	×	21 1	3,142	579	42
330	×	45 1	×	21 2	3,353	587	37
340	×	47 1	×	22 10	3,743	687	41

Now, he did not say that these were bad examples of modern vessels, but in the largest of them, with a total of 728 tons, the water ballast capacity was 272 tons short of the 1,000 tons spoken of, and would take at least 9,520 cubic feet off the cargo space if it was to be got in in the ordinary way. As to carrying water ballast in the tunnels, he knew of at least two cases in which, a few years ago, tunnels were made of double the usual strength, so that, if required, they might be utilised for the purpose. He could not find out, however, that they were so used, and would rather leave sea-going engineers to judge of the convenience and advantages of such a method. (Mr. R. H. MUIR: I filled one to-day.) That the scheme had been before the public for some time now showed the need for more water ballast, however, and emphasised the arguments of the paper. 5th, as to the utility of deep tanks, notwithstanding what had been said, an acquaintance with them of over twenty years, and the experience of a number of competent superintendents, made him adhere to what was said in the paper; and though some companies put up with them, others would not. What was wanted in ordinary cargo steamers was simplicity and efficiency and despatch, not so much in the building and repairing as in the working of them, so that loading cargo could be carrried on while tanks were being pumped out, and *vice versa*, with as little waiting, and cleaning, and fixing of gear as possible. 6th, as to making cargo steamers of leaner form and a lower coefficient, in order that they might not have trouble in getting about in ballast, he would remark that so long as vessels earned freight by carrying either dead-weight or measurement cargoes at a moderate speed such a suggestion was not likely to be adopted.

Regarding the remarks made by the speakers that evening, in so far as his reply had already dealt with them, he would not repeat what he had said. He thanked Mr. R. H. Muir for his appreciative remarks. The fact that the question of efficiently ballasting steamers had been raised in the House of Lords, as he pointed out, showed the great interest which the subject generally was attracting. Mr. Muir was very favourable to the side tanks, and, giving some good reasons in favour of them, declared his opinion that the fitting of such tanks would be a thing of the future.

With many of Mr. Batey's remarks he quite concurred. But as to the difficulty of constructing side tank steamers, the firm which was building the first one did a considerable amount of repair work, and frequently, at the present time, they put tanks into ships under the boilers without disturbing the boilers, and when work like that could be

done in the confined spaces in which they had to do it in small vessels, it seemed practicable enough to work in the side tanks where a man could stand erect and have sufficient room to strike a blow with a heavy hammer. The cost had been gone into: it was a matter for the owner and builder, but he did not think there would be any disappointment on that score. The difficulty of making the tanks to stand the pressure of water would not be so very great, for, as the President told them, much experience had been gained in building big oil tank vessels, in which large flat surfaces of bulkheads were made to stand a very severe test, and sometimes proved tight at the first filling. He thought that owing to the form of the vessel, especially near the bilge, and with her stiff and rigid framework, that the side tanks would be much stronger and less likely to leak under test than the bulkheads to which he had referred. He did not think that the deep tank proposed, with an extra winch, would be a solution of the problem of ballasting. That method had been tried, and would, no doubt, be tried again, but it depended upon the trade for which ships were to be used, and how far experience with the new system would show its utility, which of these forms of tanks would be generally adopted.

Mr. James remarked on the extreme proportions of vessel H, 338 feet by 51 feet. Builders were driven to such dimensions, however, by owners, who found that they suited their requirements. So there were a good many men and circumstances responsible for such proportions, and these were developments they could not stop. Whenever advantages were seen to lie in any direction, owners naturally followed after them. They might overdo it; but with sufficient ballasting and strong ships, he did not think they would, and such ships would be safer than the older narrow and deep type of vessels. The danger of the side tanker listing through the carelessness of those in charge had been mentioned.

Mr. Jas. Thomson asked him at the last meeting how far the ship was likely to heel over with the tank on one side only filled. Well, the largest tank was to hold 160 tons. In the ballasted condition the metacentric height had been estimated at from 8 feet to 9 feet, according to the position of the bunker coal. Now, the moment of 160 tons removed from one side, at a distance of, say, 24 feet from the centre, when the displacement is over 4,000 tons, and the metacentric height so great, would not be a serious matter; but it was found that not more than 100 tons could run out of the tank if injured by collision, as the inclination was so slight that there would still be 8 or 10 feet of water left at the bottom of the tank, so that the vessel would not incline more than about

4 degrees. Supposing, on the other hand, she was loaded, and water run into a tank on one side by accident. The metacentric height might be taken as from 3¼ feet to 3¾ feet, according as the upper spaces were filled with cargo or not. Assuming that 160 tons could be run in on one side, that quantity by 24 feet equals 3,840 foot tons, with, say, 8,800 tons displacement, and there would not be an inclination of more than 7 or 8 degrees. It would be a simple matter in such cases to trim the vessel to an upright position, either by letting water in or out of the opposite side of the vessel as the circumstances required. In regard to what Mr. James said about the difficulty of access, as had already been stated, access could be got to the tanks at any time, whether cargo was in the holds or not. The height between the stringers was sufficient to allow a man to stand erect in the side tanks. These would drain comparatively dry and clean, and it would be a different thing getting about in them to crawling through the manholes in the floors of a double bottom. There was no reason why the side tanks should waste away at all. Some of the finest structures in the country were constructed with confined tubular and other parts difficult of access, and all they wanted to preserve them was simply attention. Carrying the weight out at the sides was certainly a feature in favour of the side ballast. It did not reduce the rolling, however, so much as the raising of the centre of gravity did. As to tanks on deck, he thought their effect on the ship would be good. He had instanced a case in the paper where a temporary tank had been tried with good effect, and he thought the same result would follow in other ships having tanks on deck, whether permanent or temporary. He thanked them for the kind reception the paper had got, and for the valuable discussion which had taken place on it.

The PRESIDENT said the paper commended itself very much to him for this reason: that he looked upon it as applying the scientific part of the Institution to their practical avocations; and he thought the points which had been drawn out, both by the paper and the speakers, upon it would set members thinking, and might be the means of bringing forward some important papers on the same subject in the future. He would now ask them to accord to Mr. McGlashan a very hearty vote of thanks for his paper.

The vote was carried by acclamation.

AN INSTRUMENT FOR GAUGING THE CIRCULARITY OF BOILER FURNACES AND CYLINDERS, AND PRODUCING A DIAGRAM.

By T. MESSENGER, A.M.I.C.E.

[Read before the Institution, in South Shields, on February 18th, 1898.]

It is with considerable hesitation that the writer offers to the Institution a paper on this instrument, yet as it has proved of so much value to him in correctly recording the state of each furnace for future reference, he hopes it may be of value to some of the members. It has already met with the approval of some of the Board of Trade surveyors, and others most interested in this question, who have seen it.

This invention relates to an instrument or apparatus for internally gauging and testing the circularity of cylinders, delineating the same on paper, and is designed more particularly for use with cylindrical furnaces.

Of late years the steam pressure in boilers has been greatly increased, particularly in marine boilers of the cylindrical type having circular furnaces; such furnaces are liable to become distorted after use, and it is necessary to frequently gauge them to ascertain any deformation which may exist therein. This has hitherto been usually accomplished by measuring them with a telescopic gauge in different directions, but this method is extremely inconvenient and not nearly so exact as if these measurements were taken from the centre of the cylinder, *i.e.*, radially.

The object of this invention is therefore to take these measurements radially, and to produce a diagram on a sheet of paper showing the deformation, if any, existing in a section of the cylinder as compared with a true circle.

It consists in arranging three telescopic legs radiating from a centre pin in such a manner that they all move outwards or inwards simultaneously and equally: they are placed at angles of 120 degrees one with the other, so that when the points of these three telescopic legs rest on the inner surface of the cylinder the centre pin will always be in the centre of these three points, as hereinafter explained.

A telescopic arm is suitably arranged and provided with a roller at its outer end, pressed out by a spiral spring, which arm works on the

centre pin and is moved round the cylinder; the roller moves inwards or outwards as it travels round, following any irregularities in the cylinder, and if a pencil be fixed to the sliding piece in the telescopic arm, and pressed against a sheet of paper, it will describe thereon a diagram or representation of the form of the cylinder and show if it be a true circle or any departure therefrom. From these representations it can be seen whether or not any deformation is to be found in that portion of the cylinder tested.

This result is obtained preferably in the following manner:—At the inner ends of each telescopic leg a toothed rack is fixed, and a cog wheel gears with each of these racks, the centres of these wheels being equidistant from the centre pin. A fourth wheel is placed centrally between, gearing into each of the three, the result being the centre wheel when turned in one direction causes the three telescopic legs to move outwards, and if turned in the other direction causes the three telescopic legs to move inwards, all simultaneously, and to an equal extent.

In placing the instrument into a cylindrical furnace, it is prefered to place one of the three telescopic legs vertically, resting on the bottom of the furnace, and on this leg is placed a spiral spring to take the entire weight of the instrument, which enables it to be much more readily and quickly put in place. When the points of these three telescopic legs all touch the furnace they are fixed as follows:—On the centre wheel spindle or axis is fixed a worm wheel, with which gears a worm, working in a pivoted frame, so that it can be instantly thrown in or out of gear with the worm wheel, and when the points of the three telescopic legs touch the inside of the furnace, the worm then gearing with the worm wheel, and being turned in one direction, immediately presses the points of the three telescopic legs outwards and locks them there, thus firmly fixing the instrument in position, and the worm being turned in the opposite direction as readily releases the instrument. (Fig. 1, Plate XVI.) (Fig. 4, Plate XVI.)

This worm wheel is on one side of the instrument, and the central pin first referred to is on the other side. On the central pin is suitably secured a drawing board on which a sheet of paper is fixed, and from the foregoing description it will be readily understood that if the telescopic arm having a roller at its outer end be moved round the furnace, and the pencil attached to the outer portion of this arm which moves inwards or outwards with the roller be brought into contact with the paper, a diagram will be produced accurately showing if the furnace be

true or deformed; and although the pencil will revolve in quite a small circle compared with the furnace, yet the deformities, if any, will remain full size, and therefore be apparently magnified in proportion to the circle. This enables these deformities to be much more easily read by the eye, and they can be measured as if they were full size.

It will be understood that several sets of telescope legs are required. The first set will take furnaces from 33 inches to 37 inches; the second, from 36 inches to 40 inches; the third, from 39 inches to 43 inches; and so on. The radial arm will take any furnace from 33 inches to 52 inches, and up to 60 inches if required.

This instrument, when used to a steam cylinder, requires the roller to be replaced by a pointer having a slightly rounded point, so as not only to show any deviation from a true circle, but also any scoring which generally exists in a worn steam cylinder.

The great importance of the diagram when taken is that it considerably magnifies any defects, and at the same time shows clearly at sight which are the major and minor diameters, thereby suggesting exactly the angles at which these dimensions should be taken when furnaces are examined for deformity, and also showing the boilermaker in which direction the furnaces require to be set into truth.

The pencil is preferably so set in the instrument as to describe a figure of a convenient size to suit a sheet of foolscap paper; and as this paper is usually soiled, it is best to take a tracing of this figure to be kept as a future record, and for comparison, say every year, to ascertain the increase of deformation, if any.

Explanation of Fig. 5, Plate XVII., to which Careful Attention is Drawn.

The manner in which the pencil magnifies the evils when drawing the diagram A is very startling, and unless this is clearly understood it might lead to needlessly condemning a furnace. But this method of magnifying the evils is exactly that adopted when showing the profile of a railway, viz., the vertical scale being greater than the horizontal; otherwise the inclines would scarcely be seen, just as with this instrument any small deformity in the furnace is made apparent which otherwise would escape attention.

For finding the true circle B to compare by scale with the diagram A, an easy method is to bend a small lead wire around the diagram A. This opened out straight gives the length of the circumference for obtaining the diameter of the true circle B for this comparison; or a cyclometer may be used.

The dotted line C is reduced from diagram A to the same scale as the true circle B, and the comparison of these two diagrams, viz., C and B, gives the true delineation to scale of what the real deformity is, and so enables a true opinion to be formed at a glance, at the same time correcting the startling effect of that produced by the diagram A, which so greatly magnifies these defects.

The value of this diagram A, although so startling, is that it not only considerably magnifies any defects, but it also clearly shows at sight which are the major and minor diameters, thereby suggesting exactly the angle at which these dimensions should be taken when furnaces are examined for deformity, and also showing the boilermaker in which direction the furnaces require to be set into truth.

Again, when measuring furnaces for deformity, as has hitherto been the custom by an ordinary telescopic gauge, only two diameters are generally taken in different directions, and these diameters entered in a proper form in figures, the subtraction of one from the other giving the difference, and so when wading through a sheet of these figures, say for a vessel having 48 furnaces, one's mind becomes mystified before completing the investigation.

The great point in the magnified diagram A, is that it at once so clearly brings to one's mind the real defects of each furnace, and at a glance showing the real form in every point of its circumference.

Method of taking Diagrams in Furnaces and afterwards Working them out in the Office.

The Diagram A is first taken with the instrument in each furnace, this at a glance showing in which direction they should be measured for the major and minor diameters, and also to the boilermaker in which direction to apply the hydraulic jack, so that this part may be dealt with. The sheets of paper on which these diagrams are described are then taken to the office, and the scale for drawing the true circle B ascertained as before explained; having found this scale the dotted circle C is developed by radial ordinates to this scale, then these two circles B and C show to scale exactly what the deformity is.

An actual set of diagrams taken from boilers eight years old and the instrument by which these were taken was open for inspection at the meeting. The instrument and its use was explained by Mr. Shand.

DISCUSSION.

The PRESIDENT observed that they had the advantage of not only hearing the paper, but of having before them the instrument itself.

Mr. J. H. HECK said he had read with a great deal of pleasure the account of this instrument. He had tried and examined it, and thought there was a future usefulness in front of it. It was stated that furnaces of ordinary boilers became distorted through use. Of course furnaces came down, but that was due to want of care. As long as furnaces were reasonably attended to and kept clean there was no distortion of a serious amount. Machinery, as a rule, always gave warning before it broke. A flaw appeared, and if that kept extending voyage after voyage it showed very clearly that it was time to renew it. Furnaces were also the same. If not properly treated and cleaned they came creeping in, little by little, until distortion was caused. This instrument, especially in large companies, would be of value. If supplied to a vessel, the superintendent could require a furnace diagram to be supplied, just like indicator diagrams, every voyage, and in that way could personally judge if any alteration of form had taken place, or if the furnaces and boiler had been kept properly cleaned. It was a *sine qua non* with high pressures to keep boilers quite free from scale or other foreign matter; and as neglect of this rule caused distortion, an instrument of this kind, which had been well thought out, and exhibited it in a diagram form, was certainly of use. He thought that the thanks of the Institution were due to Mr. Messenger for the trouble and expense he had taken in sending the instrument for examination.

The PRESIDENT asked them to authorise the Secretary to convey to Mr. Messenger the very hearty thanks of the Institution for his contribution.

This was cordially agreed to, and the meeting adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897–98.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON FRIDAY EVENING, MARCH 18TH, 1898.

J. R. FOTHERGILL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in South Shields, on February 18th, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Mr. H. E. J. Camps and Mr. Frank Caws to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Anderson, Thos. James, Engineer Surveyor, 2118, Strand, Galveston, Texas, United States of America.

Dunlop, John, Ship Draughtsman, 65, Sydenham Terrace, Chester Road West, Sunderland.

Moffoot, Alexander, Ship Draughtsman, 43, Bedford Street, North Shields.

Teasdale, John, Engineering Draughtsman, 13, Wandsworth Road, Newcastle-upon-Tyne.

Tocher, J. W., Shipyard Manager, c/o Messrs. Wallsend Slipway and Engineering Co., Wallsend-on-Tyne.

GRADUATES.

Bocler, Harry, Naval Architect, 20, Briery Vale Road, Sunderland.

Brigham, Malcolm, Engineering Student, Westoe Tower, South Shields.

Dickie, James, Jun., Ship Draughtsman, 18, Brinkburn Terrace, Westoe, South Shields.

Dickie, John P., Engineering Draughtsman, 18, Brinkburn Terrace, Westoe, South Shields.
Fenton, Frederick, Ship Draughtsman, 15, King Street, Jarrow-on-Tyne.
Saul, John W., Apprentice Electrical Engineer, Wainfleet, R.S.O., Lincolnshire.
Ward, Ebenezer T., Apprentice Engineer, 22, Warrington Road, Newcastle-upon-Tyne.

The VICE-PRESIDENT explained that the President had been suddenly called away, and was therefore unable to be with them that night.

AWARDS FOR PAPERS READ BEFORE THE GRADUATES' SECTION.

The VICE-PRESIDENT announced that the Council had made the following awards for papers read before the Graduate Section during last session :—

1.—The sum of £4 to Mr. R. J. N. Willcox for his paper on "Evaporation as carried out at the present time on Board Vessels of the Mercantile Marine for the Purposes of Auxiliary Feed."
2.—The sum of £2 10s. to Mr. W. Lumley for his paper on "An Analysis of Some Types of Throttling Governors."
3.—The sum of £1 1s. to Mr. F. A. Edminson for his paper on "Refrigeration on Board Ships."

The above amounts to be spent on books, instruments, or other articles which may be of assistance to the recipients.

The Secretary was also instructed by the Council to prepare a reference list of all the papers read before the section during the session, and the papers in MS. form were to be kept in the Library of the Institution for reference.

The VICE-PRESIDENT said he was sure they would all agree with him in offering their hearty congratulations to those Graduates who had obtained the awards. He thought it was a very good feature of this Institution that they were able to offer this incentive, and so encourage the Graduates to write papers, and it was most satisfactory to find these papers frequently showed considerable merit, and in some instances were quite equal to those read by their seniors at the General Meetings.

The discussion on Mr. H. E. J. Camps's paper on "Some Considerations in connection with the Transverse Framing of Ships" was resumed.

A paper by Mr. A. E. Long, M.A., on "Some Points of Interest in the Designing of Cargo Steamers" was read and discussed.

ADJOURNED DISCUSSION ON MR. H. E. J. CAMPS'S PAPER ON "SOME CONSIDERATIONS IN CONNECTION WITH THE TRANSVERSE FRAMING OF SHIPS."

Mr. E. W. De Rusett resumed the discussion on Mr. Camps's paper on "Some Considerations in Connection with the Transverse Framing of Ships." It gave him pleasure, he said, to offer a few remarks on this very copious paper. He did so with much pleasure, as he happened to know Mr. Camps personally, and the value of his work in connection with investigations of this character. He (Mr. De Rusett) would confine his remarks to one or two points only, since the paper was so comprehensive. He thought on looking through it carefully, that Mr. Camps's deductions were theoretically reasonable when advocating an increase in the spacing of the frames beyond that usually adopted in merchant vessels, that is so far as static stresses were concerned; but he thought they should approach the subject from a practical standpoint, and he observed that with full-lined vessels, the practice undoubtedly was to come back to the closer spacing. He knew that with regard to Lloyd's that they deprecated any increase of the pitch of framing beyond their rules, and he thought for full-lined light draught vessels they were wise in so doing, for, probably many present had observed, when in dry dock, the effects of slamming on the shell and framing of merchant vessels having wide spaced frames, after being buffeted about in the North Atlantic when in ballast trim. Mr. Camps referred to the wide frame spacing of Her Majesty's vessels in support of his views. He (Mr. De Rusett) thought that when considering fine-lined deep draught vessels of that character they might increase the spacing, but when dealing with full-lined light draught ocean steamers the subject needed entirely different handling on account of the slamming already referred to. In such vessels he would hesitate very much before he would increase the spacing anywhere in the fore hold. He said this after careful observation and consideration, or if he did increase the spacing of the frames he would thicken the plating, and either double the lower part of the framing forward or add an additional lower stringer, by which means the riveted connection between the plating and the framing of the ship would be increased, and the unsupported area of plating be reduced, otherwise wider spaced framing meant reduced strength of shell to resist concussion, and a reduction in riveted connection between the frame and shell. The

writer also made mention in the earlier part of his paper of the system of deep framing, now so frequently adopted. He entirely agreed with him on the value of this system, which undoubtedly was superior to a mixed framing of light angles and webs, in fact he had adopted this principle for nearly ten years, and had watched its development very carefully, to the largest class of vessels: in consequence of which he would advocate the deep girder frame in preference to webs or other compound systems. He was sure Mr. Camps was to be congratulated on the result of his perseverance in writing such a paper, and the least the members could do, considering he gave the whole of the information—*cui bono?*—would be to avail themselves of this and like valuable papers by attending the meetings of the Institution whenever possible.

Mr. T. H. Watson said there was no doubt that Mr. Camps was to be congratulated upon dealing with a subject that could not be dealt with from a practical standpoint. He had evidently taken great pains in making calculations, but the value of the paper was reduced, in his estimation, by the admission in one or two places, that it was impossible to get correct results. He took it that the vital point of the paper was the spacing of transverse frames, for all the calculations seemed to hinge round about that. If they referred to the paper, it would be seen that Mr. Camps admitted (page 99) in reference to the formula which he gave, that the constant 500 was a doubtful factor. It would be needless to say that if the constant 500 was a doubtful factor, there was no room to dogmatise to Lloyd's Register as to the spacing of frames, because the result would be of a doubtful character. That would be something like "jumping out of the frying pan into the fire." Another point which had been stated by Mr. Camps in his paper, and Mr. De Rusett that evening, was that warships' frames were spaced wider. That was so, but it was doubtful whether warships had a greater unsupported area of shell plating. He (the speaker) thought longitudinals were fitted about 4 to 5 feet apart, with transverse frames 4 feet apart: the unsupported area in that case would be about 20 square feet, and if they took a merchant ship as at present fitted, the unsupported area ran about the same—16 feet to 20 feet. These were only rough figures, which might need slight alteration. There was no doubt at all, as far as the ideas of practical men were concerned, that if the frames were spaced wider apart and longitudinals spaced nearer in merchant work that a stronger ship would be got. This was admitted by all the experts of the country, and by everybody that had looked into the subject. In other words, there was a

superabundance of transverse strength which could be decidedly better disposed. Of course, it was a good thing to call the attention of practical men to such a subject as this; but he should say they ought to be very careful in regard to the treatment of formulæ. He had not had time to look closely into those used. He would like to ask: Were they applicable in the case of ships? Were they formulæ used for ordinary beams? If so, was it right to take formulæ used for ordinary beam strains and apply them in their ordinary way of application to ships which had so many various and complex strains? Was it possible at all, to come at the strains which a ship was subjected to? Mr. Camps had taken a ship upright in still water, and taken the pressure as two-thirds of the depth; but let it be working over to an angle of, say, 30 degrees in a sea-way, and where was the strength required? Supposing they had a ship with a double bottom right fore and aft, carrying 10,000 tons of cargo, then besides the 10,000 tons of cargo in the hold they had 10,000 tons of buoyancy-pressure outside the ship, and these two pressures, if there was no water in the ballast tank, tended to crush up the ballast tank, then would it be safe to space the framing wider with the present longitudinal spacing? He thought their experience of the past, in the case of stranding, would not justify any alteration. He was of opinion that the pressure of the cargo inside and the buoyancy outside the limits of the tank were the worst features in strain they had to meet regarding frame spacing: far more than the side pressure, for the pressure of buoyancy on the side of the ship was scarcely equal to one-sixth what it was on the bottom, and if they took the case he had stated it was almost (roughly speaking) twelve times more. Mr. Thompson, at the last meeting, told of a ship he had built with transverse frames 3 feet apart, but he did not tell them what the supported area was, or if the rigidity was made up in some other way. He congratulated Mr. Camps, but as an old friend of his, he should like to have kept out of this discussion. What he had said was not in a severe spirit, but simply to help this big subject to some practical solution, which appeared at the present time to be impossible. Still they did not know: the discussion, he hoped, would lead to some happy, bright idea which might assist in solving the problem.

Mr. Frank Caws said he had read this paper somewhat differently from Mr. Watson, for the author's statements did not appear to him to be in conflict with Mr. Watson's view as to what was the greatest stress that would be brought by water pressure against a ship; but the paper, as he (Mr. Caws) understood it, dealt more particularly with what they

must all acknowledge to be a very severe stress, and, with all due deference to the last speaker, his own opinion was that it was a very much more severe stress than the one Mr. Watson had spoken of. Mr. Camps did not treat so much of the pressure of the water against the side of the ship as of the pressure of one vessel closing, grinding, and jarring against another, or against a quay wall; and he did not attempt to give the amount of that pressure further than to regard it as the most severe to which a vessel is ordinarily subject. He assumed it may act on a certain point of the ship's side or thereabouts, and then, without pretending to estimate (as would be impossible) exactly what that pressure would be, he went on to examine the strength of the ship at that part, and to see how much side pressure the ship would bear at that part, without passing its limit of elasticity, so that when the stress was removed the ship would be self-restored to her original shape. He (Mr. Caws) thought that in these respects the method of reasoning pursued by the writer of the paper was original and quite justifiable. At the same time, he quite appreciated and united with the view of the last speaker that the pressure of the external displacement meeting the internal deadweight would undoubtedly take effect most severely on the floor of the ship; but as to whether the frames being more widely placed would so weaken the ship as to render her unable to withstand that vertical pressure, was a very wide subject which he would not now attempt to discuss. There were, however, one or two other points in the paper to which he would like to draw attention. In reading the paper he was greatly struck by the modesty of the writer. It seemed to him that Mr. Camps had written a paper, very valuable in its suggestiveness, without himself forming a very high estimate of what he had done; and in that respect he noticed one feature (or rather the absence of a feature) which he thought nothing but the writer's excessive modesty accounted for. The title of the paper related expressly to considerations affecting the transverse framing of ships. But the author had left out his own proposed special improvement in ship construction, and on being privately asked why he had done so, he said he did not like to announce l own work. He (Mr. Caws) thought it a pity Mr. Camps should thus over and ignore his own work when, as in the present case, it bore very distinctly on the subject in hand. Now, the point in question was with reference to the hold stringers. Mr. Camps, in his paper, had dealt with these features, assuming that they were constructed in the ordinary manner. It was evident from the diagrams that he had made his calculations upon that basis; but independently of that altogether, and

quite apart from the preparation of this paper, Mr. Camps, as a practical naval architect, had previously worked out a system or method for improving the construction of these hold stringers, and he (Mr. Caws) held in his hand a sheet of sections (see Plates XVIII. and XIX.) giving specimens of the method by which Mr. Camps proposed to construct these features. He thought these diagrams gave a further elucidation of the subject of the paper, seeing that hold stringers were connected with the frames, and that the title of the paper was "Some Considerations in Connection with the Transverse Framing of Ships." In order to justify what he had said, he would read a few particulars from this sheet of sections. There were four specimens of hold stringers, which appear to be designed for four different ships, numbered 1, 2, 3, and 4, and in each of these specimens the usual method of constructing the hold stringers was compared with the proposed method, and this was how the two methods compared: By the present method the sectional area of the No. 1 stringer was 23½ square inches, and the bending moment was 1,699 inch-tons, but by Mr. Camps's proposed new method the sectional area was only 14·85 inches, and the bending moment was 1,911 inch-tons. So that for very much less sectional area and correspondingly less weight a much greater bending moment and correspondingly greater stiffness would be obtained. Now, by the ordinary pattern No. 2, a sectional area of 23¾ square inches gave a bending moment of 2,241 inch-tons, while by the new method 15·7 square inches sectional area gave a bending moment of 2,284 inch-tons, so that here again they had a sectional area of 15·7 as compared with 23·75, giving practically the same or even greater strength. He submitted that that was very important. They had in No. 3 design sectional area of 18·99 square inches by the old method, giving a bending moment 1,339 inch-tons, as compared with a sectional area by the new method of 13 2 square inches and the same bending moment 1,339 inch-tons, again showing a decided advantage. In the last example on the sheet, viz., No. 4, they had a sectional area of 12·42 square inches, and a bending moment of 348 inch-tons by the old method, as compared with the new method of 9·5 square inches sectional area, and a bending moment of 351 inch-tons. He thought this sheet of sections would be a very useful and practical contribution to the subject if embodied with the printed *Transactions*, for with the diagrams before them they would see how (if the figures on the sheet were correct) they could get the same strength with considerably less weight of material. So far as he understood it, this new method, which appeared to be patented, obtained its excellent results by means of sections

specially rolled, having the larger flanges placed further than ordinarily from the neutral axis, so that their sectional area obtained more stiffening leverage, and thus made the new kind of hold stringers either much lighter for the same stiffness or much stiffer for the same weight, as compared with hold stringers now in common use. Moreover, these specially rolled hold stringer sections involved less riveting than by the ordinary built-up method, and he (Mr. Caws) thought they would all agree with him that where all other things were equal, the fewer rivets the better. He thought if Mr. Camps had put that important result of his inventive faculty into his paper on this occasion nobody would have blamed him for doing so, for it seemed to belong to the subject. Another point he should like to call attention to in regard to the general question, as to whether frames could be safely placed wider apart, was that the writer of the paper indicated that the tendency of the shell plating to buckle under longitudinal compressive stress was one of the limitations. In fact, he said it was the first limitation which occurred, and which prevented the wider spacing of the frames. Now, in that connection he should just like to mention one thing which struck him very powerfully, viz., the great superiority of those joggled shell plates recently introduced by Messrs. Doxford, in this respect, that when it came to a question of the shell plating resisting compressive longitudinal forces in the process of sagging or hogging, then he thought the joggled shell plates had a special value, through their flanged shape, which certainly enabled them to offer much greater resistance to buckling under fore and aft compression. He would not detain them by any more remarks, except to say that, although he had not found time to examine the details of the writer's calculations, and though the writer himself frankly stated, and repeatedly stated, that the subject, from a purely mathematical point of view, could not be explored, the stresses being too complexedly extended to permit of definite measurement, yet certainly he (Mr. Caws) thought they must all approve of the way in which Mr. Camps had gone about the work of analysis, as showing generally, if not particularly, the tendencies of these incomputable stresses, and as giving them one and all, as students of a difficult problem, a more thoughtful appreciation of the case than they ever had before. He, therefore, felt personally very much indebted to the writer of the paper.

Mr. G. M. Brown said it seemed to him that Mr. Camps led them to understand in his paper that the maximum stress on any frame was 28 tons per square inch, and on that assumption, he used a formula for the limiting deflection, viz. :—

$$d = \frac{L}{500}.$$

Now, he thought Mr. Camps was not quite right in using the stress of 28 tons per square inch, for that was the breaking strength of the material. Long before that stress was reached the plating and frames would be permanently deformed. Moreover, the formula for the deflection of a beam loaded in the middle,

$$d = \frac{WL^3}{48EI},$$

is obtained on the assumption that the strain is at all points proportional to the stress, and cannot therefore be expected to apply when the elastic limit is passed. Another point was in connection with the formula—

$$d = \frac{L}{500}.$$

This formula would doubtless be quite correct if they could make the beams perfectly similar as regarded the ratio of depth to span and as regarded the distribution of the material over the cross section; but Mr. Camps did not give any guarantee that the beams to which he applied this formula were exactly similar; in fact, Mr. Camps applied it to both frames and stringers, the proportions of which differed widely. Therefore he did not think that the indiscriminate use of this one formula was justifiable. The greatest safe deflection a beam could have was certainly proportional to the length, but it depended also on the ratio of depth to span, and on the distribution of the material in the flanges and webs. As length of beam increased, of course the safe deflection increased. To illustrate this point he had worked out a case or two from the formulæ used by Mr. Camps. He found that when the ratio of semi-depth to span was 1 : 12, the limiting deflection was

$$d = \frac{L}{1530}.$$

When the ratio of semi-depth to span was 1 : 63 the limiting deflection was

$$d = \frac{L}{291},$$

and not L ÷ 1,530. Again, with a ratio of semi-depth to span of 1 : 43 the limiting deflection was

$$d = \frac{L}{427}.$$

Now, the great difference in these figures, he thought, supported his objection to Mr. Camps's use of the one formula. With these exceptions, he thought Mr. Camps's paper was very interesting. Mr. Camps, if he had done nothing else, had shown the difficulty of estimating

with any degree of accuracy the stresses to which the frames and plating of a ship were subjected, even under the simple conditions he assumed. How much more difficult, then, must it be to get any idea of the stresses when the ship was at sea and being buffeted about in the manner so well described by Mr. De Rusett.

(COMMUNICATION.)

BIRK HEADS, MARLEY HILL, SWALWELL, R.S.O.,
March 28th, 1898.

DEAR MR. DUCKITT,

With reference to my remarks at the last General Meeting it will perhaps be as well for me to state how I arrived at some of the figures given therein, in connection with the "limiting deflection" of beams.

The formulæ from which they are derived are :—

$$d = \frac{WL^3}{48EI} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$M = \frac{fI}{y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

For a beam loaded in the middle we have also $M = \frac{WL}{4}$, and using this and (2) we get in place of (1) :—

$$d = \frac{L^2 f}{12\,Ey},$$

which may be written in the form :—

$$d = \frac{L}{\frac{12E}{f} \times \frac{y}{L}}.$$

Taking for illustration the case of a rectangular section, or any section in which y is half the depth, and assuming the elastic limit of mild steel to be $8\frac{1}{2}$ tons per square inch, we have in the case of a beam whose span is twelve times the semi-depth y,

$$d = \frac{L}{\frac{12 \times 13{,}000}{8\frac{1}{2}} \times \frac{1}{12}}$$

$$= \frac{L}{1{,}530},$$

and similarly for other beams in which the ratio $y : L$ is different.

Yours faithfully,

GEO. M. BROWN.

The VICE-PRESIDENT said he did not propose to ask Mr. Camps to reply to the discussion that evening, as the various speakers had introduced matter of great interest and which, no doubt, Mr. Camps would desire to fully consider. He, therefore, declared the discussion now closed, and Mr. Camps to reply at the next meeting. He thought Mr. Camps should be well pleased with the diversity of the criticism, which strongly established the value of his paper. It had always been a pleasing feature of their meetings that gentlemen did not hesitate to come forward and give their views, and although they might be quite opposed to the writer of the paper, yet it was done in such a friendly manner that the writer could not feel other than flattered.

SOME POINTS OF INTEREST IN THE DESIGNING OF CARGO STEAMERS.

By ARDAGH E. LONG, M.A.

[Read before the Institution, in Newcastle-upon-Tyne, on Friday, March 18th, 1898.]

Numerous papers have been read before this Institution upon the relative value of different types of vessels, and upon their structural strength. In the following notes the writer takes up what may be called a later stage, where the general type of ship having been decided upon, the designer has to select suitable dimensions, and work the given requirements into the best form practicable for a sea-going vessel.

The subject is much too large to be completely treated of within the ordinary limits of a paper, therefore the points of interest selected are those which may be readily discussed; the object being more to elicit a useful discussion than to dogmatically lay down the writer's own views.

The Dimensions and Coefficient.

The selection of suitable dimensions to carry, say, a given deadweight, is a much more difficult problem than it appears to be at first sight. Questions of costs, rules of the registration societies, draught of water, stowage of particular cargoes, etc., all interfere with the production of an ideal vessel from a theorist's point of view, and the resulting compromise is generally far from being satisfactory to him. The student of pure naval architecture would probably want for the purpose a relatively large vessel, while, on the other hand, the financial man wants small dimensions to reduce cost, and small draught to extend the vessel's sphere of action.

Keen competition, both amongst owners and builders, has gradually pushed the financial side of the question to the front at the expense of the other. Whether the recent advances in proportions and fulness are really advantages, even from a commercial point of view, is questionable. The respective values of the three dimensions, length, breadth, and depth, can be best illustrated by considering how much of each separately is required to obtain a given increase of displacement when working

from a previous design. We will take for our example a vessel of such dimensions that the question of Lloyd's numerals will not interfere with the comparison. The ship is, say, 400 feet by 50 feet by 34 feet 6 inches, mean draught 26 feet, 11,460 tons displacement, and about ·77 block coefficient. It is required while retaining the same coefficient to increase the displacement to 11,900 tons. This can be done by adding 16 feet length, or 2 feet breadth, or 1 foot 6 inches depth, the latter giving an increase in draught of 1 foot. The respective additions to the structural weights will be about 100 tons, 48 tons, and 33 tons. In the case of length the freeboard rules would require an addition of depth, but to avoid confusing our example we can assume that the sheer is increased sufficiently to allow us to retain the same depth, weight being allowed for this. The costs need not be here gone into, but would be nearly proportional to the added weights. The great economy of depth as a means of getting displacement is clearly seen in the foregoing, and when it is recollected that depth is a valuable element for structural strength, and that a relatively deep draught vessel is usually an easy one in a sea-way, it is greatly to be regretted that limits of draught in mercantile harbours and the Suez Canal debar the designers of modern large vessels from going to anything like the draught that they know to be desirable. As a contrast to depth the great cost of length is very apparent, and it is not surprising that where draught is so strictly limited, breadth, which is a much less extravagant dimension than length, should be so largely used, especially now when the old idea that breadth in itself is antagonistic to speed is abandoned.

The foregoing is rather an elementary method of looking at the question, and a further going into details will indicate that length is even more inefficient for our purpose than we have shown. Lloyd's rules put a heavy penalty upon lengths beyond certain arbitrary proportions to depth; in fact, beyond 13 depths it is almost prohibitive. The ground for this penalty is the excessive strain put upon the structure of the vessel by increasing her length with a constant depth. We are, however, left at complete liberty to go to any ratio of breadth to depth, although we may thereby produce a vessel which will strain severely by excessive stability.

The problem that usually presents itself to the designer is generally stated in the form of increased deadweight, not as we have taken it, displacement; and this aspect of the case tells still more against length, as we would require a further addition to make up for the increased weight. Length also, as has been previously mentioned, is an element in

the freeboard tables, and any small increase involves an addition to the depth, reduction of draught, or increase of sheer. When we take into consideration Lloyd's numerals there is another objection to using length largely. In modern double-bottom vessels a change of longitudinal numeral is of much more importance than one in the transverse numeral, as the shell, double bottom, decks, extreme proportions are all governed by the former. The very large increase in length required to get a small addition to the displacement is thus very objectionable from a financial point of view.

A curious anomaly with regard to depth may be here mentioned as a contrast. It is in many cases possible, owing to the working of Lloyd's extreme proportions rules, to increase the depth, and consequently the size, of the vessel with an actual reduction of structural weight, as the additions for extreme proportions of length to depth may easily exceed what we add to the weight by adding to the numerals.

Breadth is, as we have seen, about one-third more costly than depth, while being itself about one-half that of length; it has the advantage over length and depth in that it does not directly appear either in the extreme proportions table or in the freeboard rules. It also appears only once in Lloyd's numerals, instead of twice for the depth. From the tendency of modern practice to take breadth in excess, this latter feature of the numerals is rather regrettable, as an increase of the tax upon breadth and a corresponding reduction for length and depth might prove a wholesome check upon excessive stability proportions.

The proportion of length to beam is frequently discussed as if it practically fixed the stability of the vessel: proposed dimensions are condemned because the length is too many "beams" to suit the critic's ideas, without any regard to the really important proportion of depth to breadth. The reason for this strange mode of treating the question is probably due to the fact that on other grounds depth, roughly speaking, varies as the length; but the possible differences are so considerable that serious errors may arise from this summary treatment of stability. A little consideration will show that no proportion of length to breadth is necessarily unstable, provided that the depth is suitable to the breadth. A stiff ship of, say, 8 beams may, as far as stability is concerned, be increased to 50 beams or more.

The changes in proportions within the last quarter of a century have been curious, and traceable in some instances to imperfect conceptions of the behaviour of floating bodies. The narrow three-decked vessel, about the dangers of which so much was written, sprang from the idea

that increase of breadth meant increased resistance, and somewhat hazy notions of stability. Greater breadth relatively to both depth and length came into fashion first as a correction of the lack of stability, but another influence came later into prominence, and many modern steamers so far from being deficient in metacentric height, are seriously overdone with it. The early cargo steamers, owing to their small size, were given without disadvantage relatively considerable draughts, and in that respect were better than many vessels now built. The size of vessels has rapidly grown, but no corresponding growth of available depth of water has followed, consequently expansion has had to be in the direction of either length, breadth, or both. It has already been shown why breadth has had the preference, and the increase of breadth, with a nearly stationary depth, has produced vessels with some highly objectionable features. The metacentric height, even when loaded chock full, is frequently over 3 feet, and when in ballast G.M's. of 7 to 10 feet are not uncommon. The proportions also are such that no ordinary mode of fitting water ballast will give a reasonable immersion of propeller; and when we add to this excessive rolling, the performance of such a vessel in a sea-way is necessarily very poor, if a stronger term might not be applied. The small immersion of rudder also tells heavily against the steering, especially in very full vessels.

It is a serious question whether the mania for breadth and fulness has not been carried a great deal too far for practical purposes, and whether a rather finer, narrower, and larger vessel would not in the end more than make up for her larger first cost. The working expenses would probably be less, as better and more regular passages would be made; cargoes could be carried which would almost knock the wide vessel to pieces, and some other minor advantages would accrue.

The introduction of large cargo carrying spaces upon the upper deck has much complicated matters, as a ratio of breadth to depth, which gives a satisfactory G.M. when these spaces are full, gives an excessive one when in ballast or light.

In fixing upon the proportion of depth and breadth errors may easily be made which afterwards are incurable, so that a little care in this respect is necessary. One of the cases where insufficient consideration may lead to serious mistakes is where sufficient notice is not taken of the effect of these very large deck erections upon the vertical centre of gravity when loaded. To check proposed dimensions a convenient way is to calculate from the drawings of vessels of the required type, whose

centre of gravity in different conditions is known, a maximum ratio of depth to breadth, which will give some standard metacentric height. As this is for a rough guide to dimensions it is not altogether desirable to select an actual minimum value, but some height which will allow a small margin for differences in deck fittings, etc., in vessels of the same type. A standard height of 1 foot appears to meet the case, and the necessary calculations can be easily made, as the inclining of vessels for their centre of gravity is now a common practice.

When a table of these proportions for various types and sizes has been made, or, better still, a diagram, no error can arise in the preliminary work. The ratio of depth to breadth will vary in large vessels as generally fitted from about ·63 in complete shelter deck vessels to nearly ·70 in vessels having no cargo erections. A table giving *minimum* ratios might also be useful in places where very broad vessels are built, to avoid excessive height of G.M. It might seem at first sight possible to construct such tables as would be universally applicable; this, however, is not the case, as differences in rise of floor, relative fulness of water-lines, above and below, might make proportions satisfactory for one designer and unsatisfactory for another.

The advance in block coefficient of displacement is a subject upon which most designers are agreed, namely, that it has long since passed the bounds where it is possible to make a desirable vessel, and it is to be hoped that further experience of vessels beyond ·8 coefficient will lead to their dropping out of fashion in the same way as the old unstable three-decked vessel. As before pointed out it is probable that, even from a commercial point of view, better results would be obtained by a considerable retrograde movement, and this is a serious question affecting shipowners.

For some time after coefficients began to develop rapidly the designer was, to a certain extent, enabled, by reducing rise of floor, lengthening the parallel middle body, etc., to maintain reasonably fine ends; now, however, the midship section is so nearly rectangular that with the present form but little more can be got in that direction. The parallel body is as long as practicable, and there is nothing left but to fill out the extreme ends. As experience seems to show that the behaviour of the vessel is largely governed by the fulness or fineness of the extreme ends, a further advance in coefficient will speedily render an attempt to get fairly good steering qualities, and efficiency of propeller, impossible.

Arrangement of Displacement.

The best longitudinal arrangement of the displacement, as shown by the curve of sectional areas, is an interesting problem, and upon it a a good deal of the efficiency or otherwise of the vessel depends. Practically, the choice of form is between that having a short middle body and full ends, and one having a longer middle body and finer ends. The two types are shown in a rather exaggerated way in Fig. 1 (Plate XX.). Type A is the older, and has now been to a considerable extent replaced by type B. By extending the middle body, a corresponding piece of area can be removed from the ends, giving a better bow for driving against a head sea, and a cleaner run aft for the propeller and rudder.

Where there is any difficulty in getting stability form B is greatly superior to form A, as the form of the water-lines, following the general character of the curve of sectional areas, yields a greater moment of inertia by removing the part X to Y, where it is at a considerably greater distance from the middle line, and so gives a greater height of metacentre above the top of keel. The relative fulness of the fore and after bodies is generally indicated by the longitudinal position of the centre of buoyancy when the vessel is down to her load draught and trimmed on an even keel. This point is a convenient one, but rather too much importance is sometimes given to its exact position, some designers having a particular location for it, from which they are very loath to depart. The reason why considerable latitude appears to be allowable from a resistance point of view is that while keeping the same position for the centre of buoyancy, a great variety of form of ends is possible. Ships having sectional area curves of the types A and B (Fig. 1, Plate XX.) may have the centre of buoyancy in the same position, but their merits may be very different. In old vessels the after body was generally made the fullest, and the centre of buoyancy well aft; in fact a study of the lines of some of these vessels would almost lead one to suppose that the designers considered that the resistance of the after body and efficiency of the propeller were subjects which might conveniently be neglected. Modern practice is rather a reversal of this, as we find vessels built for special purposes with their centre of buoyancy a long way forward of the middle. Many of these craft are excellent performers if the arrangement of the extra fulness forward is carefully made so as to avoid too blunt-ended a bow. The question of trim is an important one in the disposition of displacement, but is too large to be adequately dealt with in a subsection of a paper; but it may be

mentioned that many vessels which now trim by the head when loaded full might have been designed to trim on an even keel, or by the stern without detriment to their general efficiency in other respects.

The form of the vertical sections appears to be very important for good sea-going qualities, especially those of the fore end, and care in designing them will generally be very well repaid. The midship section in old steamers generally had a considerable rise of floor, easy bilge, and a good deal of tumble home. The high bilge was almost a necessity in the narrow three-deck vessels for stability, but strangely enough their designers often overlooked the great loss of transverse moment of inertia of load-line caused by starting the tumble home low down. This was a curious error for men who discussed keenly small differences in rise of floor. The march of block coefficients has driven the modern designer to a midship section closely approaching a rectangle; this, while being very desirable for the sake of the ends, has some disadvantages as a set off against its merits. The weight of the double bottom or floors is increased, but, on the other hand, there is more capacity for water ballast. The greater girth may get us into unpleasant relations to one of Lloyd's grades—a serious matter in some cases. The filling out of the bottom of the displacement curve also makes the vessel more difficult to ballast down to a respectable draught. On the whole, however, the full midship section is a more satisfactory way of disposing of displacement than in very full ends.

The fore body sections in the early vessels were generally V shaped, both to get greater load-line area, and also to get fine lines deep down, where resistance was assumed to be greatest; this latter idea we now know to be erroneous. The chief defect of this form, apart from the excess of stability which it would give broad vessels, is that the maximum angle of entrance is at the water-line; and as diverging wave-making, which is a surface phenomenon, is governed mainly by the fulness of the vessel near the water surface, an unnecessary resistance may be incurred. Also in full vessels V sections practically mean convex water-lines at the deep draught, giving the greatest angle right forward at the stem. The wave is thus piled up into a short high form, which it is reasonable to suppose requires greater power to maintain than a lower but longer wave. In Fig. 2 (Plate XX.) the convex water-line is shown by A, where the greatest angle is at the after edge of the stem. If we carry the greatest breadth farther forward the area so gained can be cut away near the stem, giving a finer angle for a considerable distance back; B shows such a line. A still further reduction of angle may be made by filling out the lower water-

lines (generally hollow in old vessels) and cutting away an equal volume about the load-line. This alteration, in conjunction with the practice of rounding up the fore foot, gives the well-known U or club-footed sections. An additional advantage of this section is that the bow is in a more compact form, and covered by a relatively smaller wetted surface, such a reduction being especially valuable right forward, where frictional resistance is most intense. The cutting away of the fore foot may, however, be very easily overdone, and a vessel produced that hammers very badly forward in a head sea when light or in ballast.

Above water, if the U form is carried up to the forecastle, a very wet vessel as compared with the V bow, will be the result, and one very deficient in forecastle deck area.

An even drier bow than the old V can, however, be had by turning the U sections above the usual height of bow wave, out into a quick hollow flam; a hollow curve of this sort appears to have a remarkable effect in deflecting broken water outwards, even if the total overhang is moderate. The requirements of the after body are rather different from those of the fore body, and the presence of the propeller complicates matters greatly. Taken broadly, it may be stated that a form which is good for resistance is also good for efficiency of the propeller, but not necessarily so, as for instance a form of section which gives an easy flow of water to the propeller disc, may yield a greater area of surface than another which gives normal lines in a less favourable direction. As the whole volume of water meeting the propeller will have its direction to a very considerable extent governed by the form of the after body, a slight variation of form not materially affecting the resistance may greatly affect the performance of the propeller. Generally, sections which have a large amount of club foot, and are rather hollow at the height of the centre of the shaft, give normal lines more nearly parallel to the line of shaft, and at right angles to the plane of the disc, than V shaped sections do; but the girth and surface is rather more for a given area of section (see Fig. 3, Plate XX.). In special cases, such as when a full vessel has to be driven more than the usual speed, the projection of a few normal lines at an early stage of the design may be useful to show if an alteration in the shape of the sections is desirable. The value of club-footed sections aft for structural strength is too obvious to require more than a passing notice; how the older form lasted so long in fashion it is now difficult to imagine. An increase of water ballast aft, where most required, is also an advantage worth considering. One of the most important points about club-footed sections is the removal of the excessive hollow in the

lower water-lines found in old full vessels; there can scarcely be any doubt that these hollows caused a considerable amount of dead water to be carried along with the vessel, injuriously affecting the efficiency of the propeller and the rudder.

In the foregoing it has been assumed that the almost universal profile of vessel with a nearly vertical stem is adopted. It may, however, be questioned if this is really the most effective form. It is probably much superior to the old clipper stem, trail boards, etc., finishing up with a figure of a lady with curious anatomy; but some form of overhanging bow might prove better than the fashionable one. Some vessels built on the North-East Coast have a species of compromise between the straight and the clipper stem, having a slight projection at the stem head. In the specimens which the writer has seen this is carried sufficiently far to look very ugly, but not far enough to be an appreciable advantage. If a stem of this sort were carried out so as to have a curve in harmony with the general character of the hollow flam previously described, for a small addition to the weight a considerable gain in dryness could be obtained. If designed with care, the appearance —if novel—might be made pleasing, but it would be quite as easy to spoil as the double knuckle stern.

Other possible bows might be considered, such as the spoon seen on the American whale back, and modifications of it. From some rough experiments, and the surprisingly good performance of modern yachts, the writer is inclined to think that some of these forms are superior on the score of resistance to the stereotyped one. Few persons, however, who have had experience of the yacht bows, when driven hard against a head sea, would care to see the relatively thinly plated bow of a large vessel put to the same test. Apart from this structural objection, the bow is really a good one for bad weather, as but little of the apparently tremendous quantity of broken water thrown up comes on board, even when driven at a relative speed unattainable by a low-powered cargo boat. To remedy the structural weakness would probably involve such an addition to the weight as to be prohibitive from a commercial point of view.

Although this paper exceeds the usual limit of length, many interesting points have had to be altogether omitted, and those given have only been dealt with in a somewhat general manner. If, however, these notes lead to a useful discussion, and, perhaps, to some other member or members taking up the points in detail, the writer's object will have been attained.

The thanks of the author are due to Mr. W. Graham and Mr. T. L. Livingston for their kind assistance.

DISCUSSION.

The VICE-PRESIDENT said it was with very great interest he had listened to Mr. Long's paper. He thought the author had not only treated the subject in a thoroughly practical manner, but that he fully realised the modern cargo steamer, particularly from a naval architect's point of view, was a compromise. The requirements of the times demanded steamers of large tonnage, because, commercially, the larger the tonnage on a single bottom the better it paid. There could be no scientific consideration as to the relation of length, breadth, and depth in a general cargo steamer. The draught was fixed by the depth of water on river bars and dock sills, and the tonnage by the commercial requirements of the times. Of course, steamers in certain specific trades were not affected by draught, but it was an essential necessity for steamers in the general trades (and these were by far the majority) not to exceed a given draught. They thus had two definite conditions given, draught and tonnage, and with these stipulated conditions the design of the steamer had to be worked out to Lloyd's requirements, and at the lowest possible cost. Of course, the whole question was a compromise, and could not be scientifically considered under these conditions, particularly in steamers of 5,000 tons register and upwards There was another compromise which naval architects must accept: in some trades it was absolutely impossible for steamers to load or discharge without taking the bottom, and lying there during low water, with a considerable portion of their cargo in. Naval architects, no doubt, would repudiate that a ship was ever intended for such purpose. Commerce required it, the ship had to do it, and the naval architect must provide for such possibility. As to the inefficiency of propulsion of cargo steamers, particularly when in ballast, there was a very great deal to be said. Take a modern steamer leaving Hamburg or Antwerp in ballast for Cardiff, with just sufficient coal to carry her there. Suppose in rounding Land's End she experienced a heavy gale; it became a most serious matter; the steamer frequently drifting about unmanageable. The question of insufficiency of ballast required well looking into. Mr. McGlashan's paper at their last meeting had well ventilated that question. There was one peculiarity of the modern steamer when caught in a severe gale in ballast which might somewhat astonish naval architects, and which, he felt sure, they would not admit was considered in the design, and that was, experience proved the best thing to do when caught in a heavy gale off a lee shore was to drive her stern first and keep her at it.

Mr. E. W. De Rusett said this paper had given him a great deal of pleasure when hearing it so admirably read by the Secretary. He had not the pleasure of knowing Mr. Long personally, but the results of his work were well known on Tyneside in the admirable vessels turned out by Messrs. Palmer. With regard to the compromises referred to by the author, he was quite sure they could all agree with them; in fact, ship designing was a compromise throughout, and for anybody to say a ship could be built to do every kind of work equally well was a mistake. He was pleased to observe that the U sections advocated by Mr. Long were becoming more commonly adopted. He remembered as early as in 1883 advocating very strongly this type of section, together with straight or slightly convex water-lines; and, in spite of adverse views on the part of the builders, an important vessel was built on these lines, which, when on her trial trip, obtained at highest speeds an Admiralty coefficient of 284, while the builders had only expected 250, and the speed was 15·496 as against 14·5 knots guaranteed. It is interesting to note that at 12 knots the coefficient rose to 335. This took place in 1884. She proved remarkably dry and sea-worthy. The Vice-President seemed to infer that to design a full cargo boat was an easy matter. He (Mr. De Rusett) ventured to think that that was by no means the case. When they came to design to a block coefficient of ·72, it was perhaps easy, while ·77 was more difficult; but to obtain a good result with ·815 was a very difficult task, although it had been obtained in a vessel of large size with an average sea speed of 10¾ to 11 knots. Reverting to the adoption of U sections and straight or convex water-lines, he held it to be an exceedingly important matter, and thought that the eddies made by the water following in the wake of hollow lines had been overlooked for many years. His attention had been directed to this subject many years ago by the late Mr. Scott Russell during an address before the Institution of Civil Engineers, who there taught that every water-line should be of the wave form. Now, a careful study of the forms of fishes had convinced him (Mr. De Rusett) that in this respect Mr. Scott Russell was in error, for all fishes, whose forms he was acquainted with, had, with one exception, convex water-lines and U sections, but they all have a hollow curve of sectional areas. So, concluding that as they had got such a Teacher as the Creator, it were wise to follow His principle and adopt hollow lines for sectional areas, but not for water-lines. He remembered a remark in the same address which may well be repeated. Mr. Scott Russell said that water was practically incompressible between the vessel's bottom and the ocean bed, that it was practically incompressible on every side, being

bounded by incompressible shores. Therefore, the whole of the water displaced by the vessel as she sped on her course and ploughed out her own canal must be brought to the surface. His next point was that the thinner and more evenly this water could be spread over the surface, the more power would be available for propelling the vessel. But the facility with which this was to be accomplished must depend on the form of the vessel, and it was for naval architects to solve this problem. The principles advocated in Mr. Long's paper were by no means a small step in this direction, and for which they would heartily tender thanks to the author.

Mr. A. Hogg observed that in reading the latter part of the paper it was evident that Mr. Long was quite at home with the form of ships, and that made it difficult to understand what appeared an oversight at the beginning. He gave an example to show the relative values of the length, breadth, and depth in order to increase a given ship to a certain displacement, to obtain 440 tons the length was increased 16 feet, or the beam 2 feet, or the draught 1 foot; in each case the block coefficient was ·77 (same as the basis ship). The result was that the long ship was finer ended and the broad ship fuller ended than the original. In order to keep the ends of the ship practically similar, the dimensions should be about 412 feet 6 inches by 50 feet, or 400 feet by 52 feet 10 inches. The additional weights would then be 78 tons or 68 tons, instead of 100 tons or 48 tons. He (Mr. Hogg) thought the extra expense due to length which Mr. Long seemed to enlarge upon was a little bit exaggerated. In fact, there were many cases where it might be cheaper to add to the beam, but there were others where it was cheaper and better to add to the length even though they might, at the same time, require to increase the depth to keep within the rules. With the increased length they might also reduce the indicated horse-power, which might help to balance any addition due to the longer ship.

Mr. D. Andrew said this was a paper for naval architects, but putting aside the question of design on account of its commercial value, undoubtedly the old type of ship, where some regard was paid to fine lines, was preferable. From his own experience, he knew the old type as a sea-kindly ship, but this had been ignored for the full ship to carry a big cargo upon a small draught, with the result that the ship was built without any regard to its beauty, its steering qualities, or, as the Vice-President had said, to be in certain circumstances in a position to get off a lee shore. The cargo vessel of the present day was simply a big floating warehouse,

with no regard to lines to make her a sea-kindly ship. There was another feature he would like to draw attention to, and that was with regard to the masting of vessels. In the present type of ships the masts were placed only with the view of making them derricks for discharging and loading. He could look back to his time at sea on board a steamer when they met with heavy weather in the Atlantic, stopped the engines, banked fires. set the fore and aft canvas, and she would lay head to sea, be as kindly as could be, and when the gale was over, set the fires away again. They could not do that with the present type of ship on account of design and position of masts. Not being a naval architect, still he thought attention should be given in the designing of vessels, with some regard to sea-going qualities. He found that Mr. Long had drawn attention to that where he stated that beam had been rather overdone, also the fulness of the vessel. He agreed with him, and thought it time they went back to the old lines. He did not say a deep, narrow ship ; but a finer ship, and modifying to some extent this great full-bodied warehouse-style of vessel. He thought Mr. Long had opened up a wide field for discussion in that respect, and he (Mr. Andrew) hoped the Institution would take the matter up in a thorough manner, and let them have a full discussion upon it.

The VICE-PRESIDENT said he felt sure Mr. Long would appreciate the discussion that had taken place, and as the paper touched many important features he hoped members would heartily join in the discussion, which was now adjourned to their next meeting. He was much struck by the line of argument some members had taken. They appeared altogether to ignore, or forget that cargo steamers were not built or run as a mere matter of philanthropy. There was no sentiment ; they were run purely and simply as a paying commercial transaction, and they could rest assured the shipowner had a fair good knowledge as to what paid him best. Unless they could go to the shipowner and give him the tonnage on the draught which he required and built to Lloyd's requirements at a minimum cost, they might save themselves the trouble of putting forth naval architectural features, proportions, or in fact anything else, for the shipowner would not buy. The shipowner had no special interest in caring whether the ship was round, square, or oval, so long as it would carry freight to the best possible profit. He asked the meeting to join him in appreciation of Mr. Long's paper, and express it in the usual way.

The meeting then dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897-98.

PROCEEDINGS.

SIXTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUNDERLAND LITERARY SOCIETY, SUNDERLAND, ON MONDAY EVENING, APRIL 18TH, 1898.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on 18th March, which were approved by the members present, and signed by the President.

The PRESIDENT intimated that Mr. James Patterson having resigned his seat as Vice-President of the Institution, the Council, in accordance with Bye-Law 13, had appointed Mr. W. H. Dugdale to take his place. Mr. Patterson, it was explained, had gone to Belfast, and therefore could not attend. Mr. Dugdale, who was on the Council, had taken an active interest in the Institution.

ALTERATION OF ARTICLES OF THE CONSTITUTION.

The PRESIDENT, on behalf of the Council, gave notice that at the Closing Business Meeting, to be held in Newcastle upon-Tyne, on Friday, May 13th, he would move that the following alterations be made in the Constitution and Bye-Laws :—

CONSTITUTION.

Article IX.—The Council of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, ~~nine~~ *eighteen* Vice-Presidents, fifteen Ordinary Members of Council, and an Honorary Treasurer.

Article X., first paragraph.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Ordinary Members of Council shall be elected annually. The retiring Vice-Presidents *shall be those who have served six years*, and Ordinary Members of Council ~~shall be~~ those who have served three years from their last election.

BYE-LAWS.

Bye-Law 11, second paragraph.—Any voting paper returning either more or less than one President, ~~nine~~ *eighteen* Vice-Presidents, one Honorary Treasurer, and fifteen Ordinary Members of Council, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to them as Ordinary Members of Council, unless they have just completed a term of office in such capacity.

Add to Bye-Law 33.—*A synopsis of the subject-matter of each paper shall be forwarded to the Secretary, by the writer, for insertion in the circular convening the meeting at which the paper is to be read.*

NOTE.—The proposed alterations are printed in italics.

RETIRING MEMBERS OF COUNCIL.

The PRESIDENT stated that, in accordance with Article X. of the Constitution, the following gentlemen would retire from the Council:—President—Col. H. F. Swan (not eligible for re-election); Vice-Presidents—Mr. J. Gravell, Sir William Gray, and Mr. D. B. Morison (eligible for re-election); Hon. Treasurer—Mr. G. E. Macarthy (eligible for re-election); Ordinary Members of Council—Mr. W. H. Dugdale, Col. English, Messrs. J. B. Furneaux, R. Readhead, and J. Walker. (These are not eligible for re-election).

NOMINATIONS.

The PRESIDENT said that, in accordance with Bye-Law 11, on behalf of the Council, he would nominate the following gentlemen to be balloted for to fill up the vacancies:—President—Sir Benjamin C. Browne, D.C.L.; Vice-Presidents (if the proposed alterations in the Constitution are agreed to, twelve will be elected, if not, three only will be elected)—Messrs. G. H. Baines, W. J. Bone, G. Clark, Arthur Coote, John Dickinson, C. D. Doxford, Sir William Gray, Messrs. G. B. Hunter, Arthur Laing, D. B. Morison, John Tweedy, Col. P. Watts, and Mr. T. Westgarth; Hon. Treasurer—Mr. G. E. Macarthy; Ordinary Members of Council (five to be elected)—Messrs. W. Hök, W. C. Mountain, H. B. Rowell, A. G. Schaeffer, G. W. Sivewright, and Henry Walker.

The PRESIDENT said the Council had long felt that it was desirable to increase the number of Vice-Presidents with the object of enlisting the sympathies of gentlemen of importance connected with the large works, and to give them, as it were, a permanent interest in the Institution. That was the object in making the increase in the number of Vice-Presidents from nine to eighteen. It was felt also that Vice-Presidents should not be liable to be changed so frequently as three years, and therefore it was proposed that the election should be for six years. It was competent for any member at that meeting to add to the list, either of Vice-Presidents or Members of Council. If there were any new nominations he would be glad if they were handed in now.

No additions were proposed, and the list was closed.

Mr. H. E. J. CAMPS replied to the discussion on his paper on "Some Considerations in Connection with the Transverse Framing of Ships."

Mr. Ardagh E. Long's paper on "Some Points of Interest in the Designing of Cargo Steamers" was resumed and adjourned.

Mr. JAMES ANDREWS read a paper on "Cylinder Ratios."

MR. H. E. J. CAMPS'S REPLY TO THE DISCUSSION ON HIS PAPER ON "SOME CONSIDERATIONS IN CONNECTION WITH THE TRANSVERSE FRAMING OF SHIPS."

Mr. H. E. J. CAMPS said Mr Brown, in his able criticism of the paper, had objected to the use of the ratio of $\frac{L}{500}$ for the span to the deflection, on the ground that the maximum stress on the frames had been assumed at 28 tons per square inch. This was hardly so, for the deflections had all been taken as being those conforming to the safe, or, as should properly have been stated, the proof load on the frames. It was, of course, quite evident that the frames would have become permanently deformed long before the maximum stress of 28 tons had been attained. He also complained that the ratio $\frac{L}{500}$ had been used indiscriminately for both frames and stringers, when those items varied very considerably in their proportions. Now, it would be observed that as regarded the frames they were in each system of framing supported at different points of their lengths by the various stringers, which themselves gave way to a certain extent, owing to the load on the frames. In the system to which attention had been mainly confined, the points of support were proportioned off at 4 feet 9 inches, 4 feet 6 inches, and 3 feet 6 inches, but there was a definite fixed support at each end. In the case of the stringers there was no definite fixed support at each end, except at the bulkheads, which they did not deal with in determining the possible spacing of the frames.

Prof. Rankine, in his work on *Civil Engineering*, had dealt very fully with the question of deflection, and he gave the proportions as varying for working loads from $\frac{1}{600}$ to $\frac{1}{1500}$, and for proof loads from $\frac{1}{200}$ to $\frac{1}{600}$. But, independently of these ratios, Prof. Rankine gave a formula by which they might be obtained. That formula was as follows:—

$$\frac{h}{l} = \frac{n(f_a + f_b)}{4E} \cdot \frac{l}{v},$$

where $\frac{h}{l}$ was the proportion of the greatest depth of the beam to the span; $\frac{l}{v}$ the ratio of the span to the deflection; $\frac{f_a + f_b}{E}$ the proof strain,

which he gave as being about $\frac{1}{2}$ the ultimate strain; and n (a factor depending on the nature of the beam and the distribution of the load), for their particular case taken at $\frac{1}{3}$. The formula for ratio of deflection to span then became—

$$\frac{v}{l} = \frac{n(f_a + f_b)}{4E} \cdot \frac{l}{h},$$

and, utilising this, they got—

$$\frac{v}{l} = \frac{28}{3 \times 4 \times 13{,}000} \times 9 = \text{about } \tfrac{1}{600}$$

for the span between D and E (Diagram 8, Plate XIV.), and—

$$\frac{v}{l} = \frac{28}{3 \times 4 \times 13{,}000} \times 23 = \text{about } \tfrac{1}{240}$$

for the span between C and B. Now, in the latter case, between the imaginary point of loading and the two extreme points of support, which were fixed, there were two other supports which were not fixed, but still gave a certain amount of support, and quite sufficient to make a great reduction in the ratio $\frac{1}{240}$, bringing it nearer the $\frac{1}{500}$. The paper did not pretend to take the ratio as being absolutely and infallibly correct, for such would be impossible for all cases, and could only occur by guesswork and the merest chance. Therefore the ratio of $\frac{L}{500}$ was taken, not only because it was considered to be fairly close to the mark, and at any rate near enough for the purpose for which it was used, but primarily because it seemed a good mean ratio to apply to all the examples, and, by so using it in all cases, to avoid those complications which would probably have made the subject most unnecessarily incomprehensible. With regard to the stringers it would be observed that it was necessary to assume a certain ratio in order to obtain points of extreme support, or, in other words, the length was based on the deflection, and that in choosing the ratio of $\frac{L}{500}$ it made no difference to the results, which were purely comparative. He also would like to point out that, instead of the expression "safe deflection" used in the paper, it would perhaps have been better to have written "convenient deflection," as Prof. Rankine termed it; and it should also be understood that this signified convenient as against permanent deformation due to heavy strains, and not against rupture or leakage, with which, theoretically, it was impossible to deal. Again, the paper had dealt exclusively with the straight sides of the ship, and it was quite evident that on the bilges the ratio men-

tioned of $\frac{L}{500}$ would be much less, owing to the greater natural rigidity of the frames and stringers at those parts, due to form. In the constant of $\frac{1}{500}$ which Mr. Watson referred to in the formula :—

$$W = \frac{fs}{1 + c\frac{L^2}{d^2}},$$

and which was used in determining the compressive strength of the hold beams, he, unfortunately, could find no constant for mild steel pillars of the section that the hold beams were built up to, and consequently had to approximate it from the nearest that could be found, which happened to be for wrought iron pillars. For such pillars of I section, the constant was $\frac{1}{900}$, and making the necessary allowances for difference of material it would seem that $\frac{1}{500}$ was not far wrong. Later on in the paper, where the same formula had been used for finding the strength of the shell plating when under compressive strains due to hogging or sagging, the correct constant for pillars of rectangular section had been taken, viz., $\frac{1}{2400}$. It might be added that the formula used was that of Mr. Lewis Gordon. Another point which Mr. Watson raised was regarding the crushing strains on the double bottom of a vessel when loaded. Now, this did not appear to affect the argument in the paper at all; because with reference to the strength of the ship's bottom, even if the vessel were loaded to twice her ordinary load draught, were it possible, the pressure on the bottom plating *between* the frames, would still be proportional to the depth of the water, and not be affected by the cargo in the holds. And then as to the strength of the floors on which the cargo rested, there could be little doubt. For instance, if they compared two vessels, each of 400 feet length, one having a double bottom, say, 4 feet deep at the centre line, and the other ordinary floors, say, 30 inches deep at the centre line with no double bottom, which were about the actual figures, surely if the latter was strong enough to withstand the crushing effect of the cargo inside, and the buoyancy outside, the strength of the former with nearly double the depth of floors could not be called in question, even with the slightly wider spacing suggested in the paper. In respect of case cargo this could be more easily understood, for then the frame spacing, as far as the cargo was concerned, might be much wider without damaging the plating; especially in view of the distributing effect of the ceiling. The frame spacing in such cases could only be affected by the pressure of the water on the plating *between* the frames, and, as already pointed out, this pressure was directly proportional to the depth of the

water. He therefore did not agree with Mr. Watson that this crushing strain was the most severe to deal with in considering the frame spacing. As was stated in the paper, the effect of the water pressure acting on the plating had been dealt with in papers by other writers, and therefore was not touched in this.

Referring to Mr. De Rusett's remarks, he would again point out that his (Mr. Camps's) arguments in favour of wide spacing had been applied to the midship body only. At the ends of the vessel, as Mr. De Rusett justly pointed out, it was doubtful whether a wider spacing of frames than was asked by the registration societies would be advisable, on account of the severe buffeting which such parts undoubtedly received, especially in heavy weather; or, at any rate, any increase in the spacing should be attended by either an increase in the thickness of the shell plating, or in an increased number of longitudinal or panting stringers, either of which would perhaps be better than the close spaced frames, as there would thus be a reduction in the riveted connection to the shell, thereby minimising the chances of leakage. At the ends of vessels, the amount of unsupported area, mentioned by Mr. Watson, was of much more consequence than at midships, where the concussive strains were not nearly so direct or severe. He had lastly to thank Mr. Caws for introducing in the discussion a few points in connection with the hold stringers which were left out of the paper. He did not apologise for having left them out, as the paper was already too long, and he could not have done what he would have considered full justice to them. There was no doubt that the effect of the joggled shell plates mentioned by Mr. Caws as being adopted now by Messrs. Doxford at Sunderland was a distinct advantage and help to the plating generally against longitudinal compressive strains under hogging or sagging, so also was the natural form of the turret design. In conclusion, he had to thank the members for the kind way in which his paper had been received.

The PRESIDENT asked the meeting to accord a very hearty vote of thanks to Mr. Camps for his paper, which had called forth considerable criticism, to which he had that night replied. The paper was instructive, and would also, he thought, be very useful to very many of them in their daily shipbuilding.

The vote was accorded by acclamation.

DISCUSSION ON MR. A. E. LONG'S PAPER ON "SOME POINTS OF INTEREST IN THE DESIGNING OF CARGO STEAMERS."

The PRESIDENT, on inviting discussion on Mr. Long's paper on "Some Points of Interest in the Designing of Cargo Steamers," said he had a note from one of their Vice-Presidents introducing Mr. Alexander, who, though not a member of the Institution, would be glad to offer some remarks on the paper. He was quite sure they would be willing to hear him.

Mr. F. H. ALEXANDER said that, not being a member, he had to thank them for offering to listen to a few remarks of his on Mr. Long's paper, which was an extremely interesting one to him, as he had long taken an interest in the forms of vessels. He noticed a small blemish in the diagram accompanying the paper; the lettering of the lines was correct, but in one case the dotted line should have been full, and the full line a dotted one, to agree with the other figures in the illustration. There were many things in the paper which might give rise to discussion, and some which want of time had caused to be omitted. He noticed no mention of the effect of size upon coefficient, whereas it was well known that a large vessel could be made much fuller than a small one, for usual "tramp" speeds. He might also call attention to the effect of very full ends in long vessels, in causing severe sagging strains when in ballast and bunker trim. It seemed to him that the crux of the paper lay in the reference to the excessive beam and fulness of recent vessels, and the expression of the opinion that a more normal form of ship would be better, even from a commercial point of view. The writer spoke of a mania for breadth and fulness, but was it not really the mania for accepting the lowest tender which he should attack? The idea that the lowest first cost should govern the placing of an order for a vessel, had led to the evolution of these objectionable features in excess, owing to the causes pointed out in the paper. As to whether the first cost was the only thing to be looked at, he would like to give an illustration of another view. Suppose two vessels, A and B, each to carry about 5,000 tons deadweight, at 10 knots, on a consumption of, say, 22 tons of coal per day. Let A be a vessel of recent type, of great beam, easy bilge and short length, with full ends, and an almost semi-circular line for the forecastle rail. Let B have greater length, less

beam, harder bilge, and finer ends, but consequently a cost, say, £1,000 in excess of A. On trial, and in fine weather, these two vessels might perform equally well, but as soon as head winds and heavy seas were met with, the speed of A would drop lower and lower till it reached 5 knots or under; perhaps, as they had heard at their last meeting, she would have to turn stern first to the seas, and they had not been told how many knots she would go at then. The finer vessel would not be affected to the same extent, and the consequence would be that her speed, over a year's voyages, would average about 9¼ knots, while the speed of A would be only 8½. The coal consumption and other expenses would, however, not fall in bad weather with these losses of speed, and so at the end of a year of, say, 300 working days B would have gone 66,600 miles and A only 61,200 miles. From this it would be seen that the cost of carriage per ton per mile by B would be almost 9 per cent. less than by A, assuming equal average cargoes; and it would be merely a question of time and freight values how soon B would pay off that extra first cost of £1,000 and the charges upon it. It might be said that these were assumed figures, but the speaker felt sure that the experience of many would bear them out. There were many vessels whose speed seemed killed by bad weather, and there were others which nothing seemed to stop. He might mention the case of a voyage he had taken from Australia to London during the wool season, when the vessel he travelled in was racing another. They left Adelaide together, and sighted each other at intervals during the voyage, and docked in London within a few hours of each other, but it was very noticeable how bad weather injured the speed of one of the vessels, and allowed the other, a slower boat in reality, to catch up again and again. One other point he would refer to, and that was a genuine difficulty to be faced, in trying to persuade owners of the value of a finer type of vessel. They all knew that builders differed in their models, even when working to the same coefficient and dimensions. Suppose the owner of a boat of ·8 coefficient to be persuaded by certain builders to make his next one ·78, and to find the latter a great success. He thereupon ordered his next one ·78 also, but from different builders, as their tender was lower. He was surprised, perhaps, to find that this new craft was not even as good as his ·8 one, and straightway concluded shipbuilders' opinions were a fraud. He should rather conclude that he had made a mistake in not going back to the builders who had given him his successful boat before. As it was, his experience would cause some brother owner to order "a six-beam boat, with an easy bilge, and a coefficient of ·83."

Mr. ROBT. THOMPSON said Mr. Alexander's remarks were both interesting and instructive. He thought where the great discrepancy came in was that most people went in for standards. Where a shipbuilder knew his business, all these points would be brought before the shipowner. Most shipbuilders took the coefficient from the top of the keel, but he had heard of others taking it from the bottom. As to the results obtained with fine mid-ship sections or full ones, there was room for discussion, and each builder would justify himself in his own way. His view, however, was this, that any vessel having a displacement coefficient above ·8, whether it was obtained by full ends and fine bilge or in any other way, was not a ship at all. The experience owners were having with some of these very full, broad vessels in a light condition in the Atlantic proved that Lloyd's rules were never designed for vessels with such a full coefficient. A friend of his put it very neatly by calling it the "McKinley tariff." His experience of these results was that vessels were far too full. He had been in correspondence with Mr. George Dykes, of Hamburg, who had sent an amount of useful information upon Mr. Hogg's paper recently read, and he would like if it could be incorporated in the *Transactions*.* He might say he thought he recognised one of the ships referred to by Mr. Alexander. It was built in 1886, and had been one of the most successful vessels the owner possessed. She was about 4,000 tons deadweight and she averaged 11 knots.

The discussion was adjourned till the Closing Meeting on May 13th.

* See page 237.

CYLINDER RATIOS.

By JAMES ANDREWS.

[Read before the Institution, in Sunderland, on Monday, April 18th, 1898.]

Ever since the introduction of multiple expansion engines the subject of cylinder ratios, or the relative dimensions of one cylinder to another, has been a favourite theme for speculation, discussion, and experiment; while at the same time, little, if anything, has been done to reduce the question to systematic determination. The object of the present paper, therefore, is to approach the subject from this later standpoint, in the hope that it may at least confine its discursive features to narrower limits, and make experiments less costly.

It is almost needless to point out that no definite rule can be given for determining cylinder ratios which will apply under all, or even any, circumstances with great exactitude. The variations usually found in practice of steam velocities, receiver capacities, sequence of cranks, and other causes affecting the action of steam in the steam engine, preclude the possibility of such a consummation. But while that is the case, it is considered that a general rule may be formulated which, without seriously complicating the question, will give approximately correct cylinder ratios, that is to say, ratios such that by slightly adjusting the valves it will be possible to secure the maximum economy attainable within the limits of steam pressure employed on the given type of engine.

The great advantage of systematic calculation even with all its imperfections is that those elements which are known to produce the most economical results, and others which are supposed to lead in the same direction, get due consideration in the first instance, in place of, as in the majority of cases, being left to look after themselves. Moreover, changes from one set of conditions to another can be followed with comparative ease, the effect noted, and a proper selection made at once. At the present time the working conditions of almost every engine are different, the relation between clearance, initial and final volumes are often

unnecessarily varied; similarly to, with exposed surfaces and receiver capacities, so that the true cause of success or failure is obscured, and in many cases rendered quite incomprehensible.

It is submitted, therefore, that a better understanding of the question will be arrived at by making all changes from one dimension of engine to another as nearly relative as possible, so that they can be easily compared and improved upon with some degree of confidence.

When designing multiple cylinder engines, it is essential at the outset to determine certain conditions as a basis to work upon, and, generally speaking, the following ought to be fulfilled in order to secure the most economical results, alike from a practical and commercial point of view, viz.:—

(*a*) The maximum loads on each piston,
(*b*) Range of temperature in each cylinder,
(*c*) Indicated horse-powers in each cylinder,
(*d*) Rate of expansion in each cylinder,

should all be approximately equal.

(*a*) Within the limits of a given initial and final exhaust steam pressure, equal maximum loads will secure the greatest amount of power from the least weight of material, thereby reducing the first cost, wear and tear, and simplifying the balancing of moving parts.

(*b*) It is well known that the range of temperature in each cylinder should be as low as possible, and probably equal, to secure the maximum economy of steam.

(*c*) It does not appear that equal indicated horse-powers have any direct influence upon the economy of an engine; indirectly, however, they assume a degree of importance which demands recognition, from the fact that this factor is the chief engineer's standard of excellence, and since it is he who determines eventually the conditions under which an engine shall work, it is useless to design an engine upon any other basis, unless the conditions are such that no amount of adjustment of the links would produce that result. But apart from these considerations, there is no evidence to prove that equal powers are incompatible with economical results; on the contrary, with ordinary compound, triple, and quadruple expansion engines, completing each stage of expansion in one cylinder, there is evidence of an approximate coincidence, both theoretically and actually, with those elements which are considered most conducive to economy, as will be shown later on.

(*d*) Equal cuts-off are preferable, in order to keep the initial volumes and initial surfaces relatively equal in each cylinder, as well as being more convenient from a practical point of view.

Having now decided upon the principal factors, the *modus operandi* may be described as follows, taking for that purpose the simplest case of a multiple cylinder engine in which expansion is completed in two stages. Let Fig. 1 represent the combined diagram of a compound engine in which—

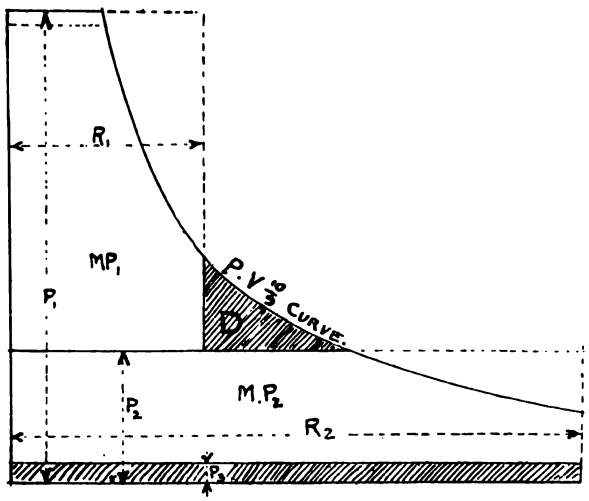


FIG. 1.

P_1 = mean initial pressure absolute.
P_2 = mean receiver „ „
P_3 = mean back „ „
MP = mean pressure reduced to L.P. cylinder.
MP_1 and MP_2 = H.P. and L.P. mean pressures respectively.
R_1 and R_2 = relative volumes of cylinders.
r = total rate of expansion.
r_1 and r_2 = rate of expansion in H.P. and L.P. cylinders respectively.
D = fraction of "drop area" relative to the whole diagram within the limits of P_1 and P_3.

The expansion curve being for saturated steam $P.V^{10/9}$ = constant. It is preferable to state the question with reference to equal powers and equal ratios of expansion in each cylinder, because the process of trial and error which must be gone through is rendered much more simple, and, provided that each stage of expansion is completed in one cylinder, the result is practically the same. Therefore, given equal powers and equal rates of expansion in each cylinder, it is required to find the cylinder ratios.

$$MP = \left[P_1\left(\frac{10}{r} - \frac{9}{r^{\frac{10}{9}}}\right) - P_3\right](1 - D).$$

$$MP_2 = \frac{MP}{2}.$$

$$P_2 = \frac{MP_2 + P_3}{\left(\frac{10}{r_2} - \frac{9}{r_2^{\frac{10}{9}}}\right)}.$$

$$MP_1 = P_1\left(\frac{10}{r_1} - \frac{9}{r_1^{\frac{10}{9}}}\right) - P_2.$$

$$R_2 = \left(\frac{P_1}{P_2}\right)^{9}.$$

When $R_2 \times r_1 = r$ and $MP_1 = MP_2 \times R_2$ the cylinder ratios will be correct as required, but this may involve the variation of r or $(1 - D)$, or both. It is not quite correct to eliminate the drop area without some compensation for the heat liberated by free expansion into the receiver, but the error involved appears to be insignificant for the present purpose. The difficulty of determining its actual effect is greatly increased from the fact that variation of drop in a given engine involves the variation of so many other elements that the true cause and effect of one or the other cannot be separated. All variable quantities have been left out of the question, partly to avoid complication, which would render the whole process almost useless for the purpose intended, and partly because one set of conditions affect cylinder ratios in an opposite direction to another set of conditions, so that to select any set of variable quantities would limit the use and application of the diagrams appended. Each designer can make suitable modifications when they are found necessary, but in general, when the cranks are arranged in the best sequence, it will be found that most irregularities can be corrected by a very slight adjustment of the links.

All other multiple cylinder engines completing each stage of expansion in one cylinder are calculated in the same way, the L.P. mean pressure being simply the product of MP divided into the number of cylinders or stages of expansion. For compound engines having two low-pressure cylinders $MP^2 = \frac{MP \times 2}{3}$ to give approximately equal powers and mean initial loads with unequal ranges of temperature. Roughly, the ratio for this type of engine is about one-half of that for an ordinary compound working within the same limits of pressure. When equal ranges of temperature are required the cylinder ratios remain the same as

for an ordinary two-cylinder compound, in which case the powers and loads on each low pressure cylinder will be about one-half of that in the H.P. cylinder. Similarly, for triple, quadruple, or other multiple expansion engines having two or more low-pressure cylinders, the L.P. mean pressure is the product of MP multiplied by the number of low-pressure cylinders and divided by the total number of cylinders. In those latter types it is impossible to combine equal initial loads and equal powers with equal ranges of temperature.

The diagram, Fig. 2 (Plate XXI.), gives cylinder ratios, total rate of expansion, mean pressure, and values of (1 — D) for ordinary compound engines; similar information is given on Figs. 3 and 4 (Plates XXII. and XXIII.) for ordinary triple and quadruple expansion engines. The mean initial pressure absolute is the average between the beginning of the stroke and the point of cut-off, while the back pressure is the average over the whole stroke as they are estimated to be obtained on the actual engine, according to the designer's practice. All the curves are calculated theoretically between those limits of pressure and by the method already described. They provide a simple means of determining the proper dimensions of cylinders in new designs to suit the circumstances of the case, and it has been found, by comparison with a number of existing engines, that the cylinder ratios are as nearly correct as it is practicable to estimate them, provided that the mean initial pressure, and especially the back pressure, correspond with the diagrams.

The following example, calculated for a quadruple expansion engine, will serve to illustrate the effect of the L.P. back pressure upon cylinder ratios, the temperature ranges, initial loads and powers remaining approximately equal :—

p_1	p_5	r_1	R_1	R_2	R_3	R_4
190	4	1·33	1	2·0	4·43	11·0
190	6	1·33	1	1·92	3·93	8·8

from which it will be seen that 2 lbs. difference in the L.P. back pressure (P_5) reduces the relation of the first to the fourth cylinder from 11·0 to 8·8. The diagrams, Figs. 5, 6, and 7 (Plates XXIV., XXV., and XXVI.) give the receiver and mean pressures in each cylinder for the respective types of engines, from which the theoretical loads and ranges of temperature can easily be found. By comparison with actual engines they may also serve as a means of localising defects or sources of inefficiency.

Small receivers have the effect of increasing the cylinder ratios in order to retain equality of temperatures, loads, and powers, but to a greater extent as regards the former two than the latter. High steam

velocities have the same relative effect as small receivers, except that the relation of the first to the last cylinder will be smaller on account of the higher back pressure on the low-pressure cylinder.

When a feed-heater takes its steam from one of the receivers, the following cylinder ratios should be reduced, while the admission of exhaust steam from auxiliary engines will have an opposite effect.

The relation between the actual mean pressure reduced to the low-pressure cylinder and a theoretical mean pressure of the whole combined diagram calculated between the same limits of pressure, constitute what is commonly called the "diagram efficiency," and may be expressed thus :—

$$E = \frac{\text{Actual MP reduced}}{\left\{ P_1\left(\frac{10}{r}\,\frac{9}{r^{\frac{10}{9}}}\right)\right\} - P_2},$$

in which P_1 is the initial pressure, P_2 the L.P. back pressure and r the total rate of expansion. The values of E so found are recorded for the purpose of estimating mean pressures for new engines, but as no account is taken of the drop area, E is a variable quantity depending upon the rate of expansion in each cylinder, and in consequence, late cut-off engines appear to be at a disadvantage as compared with early cut-off engines. In the same engine, however, it may happen that the value of E remains constant over a wide range of expansion because the amount lost by receiver expansion when cutting off late is counterbalanced by the amount lost by increased compression, release, and redistribution of the temperature range in each cylinder when cutting off early, so that the relative area of the diagrams remain the same. To illustrate the actual effect of incomplete expansion on the value of E, the following two examples of triple expansion engines of different designs may be given. Both were designed to cut off at about 75 per cent. of the stroke, and having the slide valve exhaust edges open as much as possible at both ends to get an early release, consequently the relative area of the diagrams due to release and compression at the different rates of expansion was very little affected.

	Engine A.				Engine B.			
p_1	110	109	109	109	172	172	172	172
p_2	4·7	4·4	4·1	3·8	6·5	6·0	5·3	5·0
r	7·61	8·175	8·86	10·97	6·64	6·42	6·8	7·78
r_1	1·33	1·43	1·55	1·92	1·28	1·36	1·436	1·65
Actual MP	25·75	24·55	23·62	21·3	51·59	50·03	49·21	45·71
(1 − D)	·914	·938	·962	1·0	·902	·93	·943	·9725
E with drop	·703	·720	·738	·781	·755	·761	·773	·791
E minus drop	·768	·768	·768	·781	·838	·82	·82	·814

By reference to the last two lines, it will be seen how much more uniform the values of E are when the drop area is deducted than when it is not.

With regard to the actual relation of powers, initial loads, ranges of temperature, and cylinder ratios, the few typical cases hereafter cited have been taken promiscuously from engines by different makers, so that the results are not due to any peculiarity in design. In all cases R is the calculated cylinder ratios, the affix L or T indicates equal loads, and equal temperatures respectively. R_A the actual cylinder ratios, r_1 is the actual rate of expansion in each cylinder, and relative initial loads are given in terms of pounds per square inch reduced to the low pressure cylinder.

Engine D, compound P_1 = 134 lbs.; P_3 = 4 lbs.

R.	R_A.	r_1.	I.H.P.	Initial Loads.		Range of Temperatures.	
				Mean.	Max.	Mean.	Max.
1·0	1·0	2·9	156	29·1	31·6	97°	107°
4·05	3·54	2·3	130	20·0	23·0	87°	93°
Engine E, compound P_1 = 92 lbs.; P_3 = 3·5 lbs.							
1·0	1·0	1·6	248	18·5	20·6	70°	73°
3·53	3·3	1·66	342	23·0	24·0	97°	108°
Engine F, compound P_1 = 170 lbs.; P_3 = 3·5 lbs.							
1·0	1·0	1·72	1,041	20·2	20·4	91°	98°
4·24	6·1	2·31	1,079	28·0	30·0	106°	108°
Engine G, triple; P_1 = 150 lbs.; P_4 = 4 lbs.							
1·0	1·0	1·36	677	11·65	13·43	55°	62°
2·44	2·54	1·43	693	14·20	17·38	54°	65°
6·94	6·70	1·475	787	16·00	18·00	75°	81°
Engine H, triple; P_1 = 150 lbs.; P_4 = 5 lbs.							
1·0	1·0	1·34	791	13·3	14·5	64°	69°
2·33	2·40	1·29	728	12·5	14·6	52°	66°
6·25	6·64	1·36	703	11·5	14·5	56°	67°
Engine J, quadruple; P_1 = 198 lbs.; P_5 = 6·5 lbs.							
1·0	1·0	1·33	424	12·56	13·5	65°	69°
1·9	2·04	1·33	320	9·33	9·3	45°	51°
3·9	4·2	1·33	332	10·0	11·5	46°	53°
8·5	9·0	1·33	290	8·5	10·75	39°	50°

Engine K, quadruple; $P_1 = 189$ lbs.; $P_5 = 4{\cdot}2$ lbs.

R.	R_A.	r_1.	I.H.P.	Initial Loads.		Range of Temperature.	
1·0	1·0	1·6	450	9·43	11·5	52°	65°
2·0	2·25	1·6	378	8·5	9·45	39°	44°
4·4	4·0	1·6	376	8·17	11·7	40°	57°
10·5	9·75	1·6	433	8·6	10·5	51°	61°
*Engine L. quadruple; $P_1 = 192$ lbs.; $P_5 = 3{\cdot}3$ lbs.							
1·0	1·0	1·55	210	10·9	13·1	55°	68°
2·07	2·25	1·80	159	8·75	12·7	40°	58°
4·7	4·0	1·50	178	8·9	11·6	45°	57°
11·9	9·0	1·62	171	8·2	9·0	55°	62°
Engine M. three-cylinder compound; $P_1 = 100$ lbs.; $P_3 = 4$ lbs.							
R_L.	R_T.	R_A.	r_1.	I.H.P.	Initial Loads.		Range of Temperature.
					Mean.	Max.	Mean.	Max.
1·0	1·0	1·0	1·45	5,500	28·9	34·3	65°	75°
1·09	1·71	2·185	2·87	4,260	28·0	27·5	101°	113°
1·09	1·71	2·185	3·3	4,750	30·9	30·7	106°	119°
H.M.S. "Powerful," four-cylinder triple = $P_1 = 186$ lbs.; $P_4 = 5{\cdot}8$ lbs.							
1·0	1·0	1·0	1·33	4,287	37·9	40·7	66°	79°
1·84	2·5	2·42	1·28	4,233	37·0	45·0	57°	69°
1·75	3·75	2·85	1·31	2,263	18·7	19·0	71°	87°
1·75	3·75	2·85	1·31	2,238	18·7	19·0	71°	87°

* Engine L is fitted with feed-heater taking steam out of L.P. receiver.

The mean initial loads and mean ranges of temperature are taken from the mean initial pressure up to point of cut-off, and the mean exhaust pressure in each cylinder. They are given as representing more correctly the loads and temperatures as affected by cylinder ratios apart from other causes. Many more examples could be given, but as they all point to the same general conclusion, it is needless to repeat them here. The broad facts remain the same throughout, when allowance is made for the rate of expansion in each cylinder, namely, that in multiple cylinder engines completing each stage of expansion in one cylinder, the loads and temperatures vary directly with the horse-powers; that when one stage of expansion is completed in two cylinders, the loads and temperatures while varying directly with the horse-powers are always unequal, and that in all cases the calculated cylinder ratios indicate the direction in which an improvement lies. It is an open question whether multiple cylinder engines, completing one stage of expansion in two cylinders, are more economical when designed to give equal powers and loads in each cylinder or equal ranges of temperature. For marine

purposes practical considerations have so far decided in favour of the latter, viz., the larger cylinder ratios; otherwise the cut-off becomes too early for ordinary link motion; but, strange to say, this type of engine has been adopted principally to simplify the balancing of moving parts, for which the former is apparently best adapted.

A question has been raised with reference to the proper dimensions of cylinders for H.M.S. "Powerful" to get equal distribution of powers, the answer to which is as follows:—

Taking the same total rate of expansion, the dimensions should be 57½, 78, 76, and 76 inches diameter to give equal powers with equal cuts-off at 46 per cent. of the stroke; but in order to get equal ranges of temperature the dimensions become 39, 62, 76, and 76 inches diameter with equal cuts-off at full stroke.

During last session Prof. Weighton published the result of some experiments made with the Durham College quadruple expansion engine which were intended to show the relative economy when varying the power of a given engine, first by altering the number of expansions, and, secondly, by altering the initial steam pressure; but certain general deductions were made with regard to the most economical rate of expansion which do not agree with current ideas on the subject, and which it is thought may be explained in a great measure by the cylinder ratios of the engine experimented upon and the limits of steam pressure employed.

Let it be supposed that in a given engine the powers, initial loads, and temperatures are approximately equal when the rate of expansion in each cylinder is 1·5. By reference to diagram, Fig. 4 (Plate XXIII.), it will be observed that increasing the number of expansions increases the cylinder ratios; which, with constant cylinder ratios, is equivalent to increasing the relative power, initial load, and range of temperature in the low-pressure cylinder, while reducing those elements in the high-pressure cylinder, and that the converse of this is the case if the number of expansions be reduced. On the other hand, reducing the steam pressure reduces the cylinder ratios; which, on the same engine, is equivalent to increasing the relative power, load, and range of temperature in the *high*-pressure cylinder, while reducing those elements in the *low*-pressure cylinder. In other words, varying the number of expansions or the steam pressure separately above or below that point at which approximately equal powers, loads, and temperatures have been obtained will have the effect of making those elements unequal, and if it be granted that inequality in any of those factors reduce the economy of an

engine, then the point of maximum economy is easily located. The best results should be obtained by a judicious combination of increasing the number of expansions with a reduction of the steam pressure or conversely.

In the experiments referred to, the highest limit of economy had not been reached at the comparatively late cut-off of 75 per cent. and 15·46 expansions; a result which would indicate that the cylinder ratios were too large for the limits of pressure used, and that an extension of this limit would increase the number of expansions at which maximum economy would occur, and, at the same time, increase its amount.

Some interesting experiments have been published recently in a paper read before the American Society of Mechanical Engineers by R. H. Thurston and L. L. Brinsmead.

They were made on the Sibley College triple expansion engine, which has cylinder ratios of 1 : 3 : 7, and were divided into three series, of which the first was on the compound system, having ratios of 1 : 3; the second also on the compound system, having rations of 1 : 7; and the third on the triple system, having ratios as above quoted. Each engine was tested over a wide range of total expansions, and diagrams constructed having number of expansions for the abscissæ, with pounds of steam per I.H.P. for the ordinates. The curves of the 1 to 3 compound, and the triple engine have the point of maximum economy well defined, being 15 expansions with 17·3 pounds of steam, per I.H.P. for the compound, and 22 expansions with 13·68 pounds of steam per I.H.P. for the triple; while the 1 : 7 compound had not attained its maximum of economical working at 18·89 expansions with 15·1 pounds of steam per I.H.P. Those experiments having been undertaken with a view of demonstrating, whether the abnormal cylinder ratio of 1 to 7 in the compound system was more or less economical than the normal cylinder ratios of the compound or triple system, it was essential that the comparison be made on truly normal conditions, and not upon abnormal extremes as was manifestly the case with the two compound engines. As a consequence the 1 to 3 compound attained its point of maximum economy at a less total rate of expansion than the triple which of course rendered a true comparison impossible. It is therefore not surprising that the authors should come to the conclusion that "the bearing of these results on the relative merits of the three types is a matter which experiments on one engine, and under one set of conditions cannot definitely determine."

The triple expansion engine, having approximately normal ratios, gives the following results at its maximum of economical working :—

R.	R_A.	r_1.	Relative I.H.P.	Initial Loads.	Range of Temperature.
1·0	1·0	2·7	1·0	12·2	72
2·59	3·16	3·16	1·0	13·3	61
7·1	7·1	2·16	1·0	10·0	57

Showing that the calculated cylinder ratios are correct for equal cuts-off, and correspond with the point of maximum economy; but, that the unequal cuts-off in each cylinder of the actual engine affect the loads and temperatures to some extent. A more satisfactory comparison is made between three different engines of the types referred to, in which their steam consumptions are given as 11·16 pounds per I.H.P. with 19·55 expansion, for the normal triple having ratios of 1 : 3 : 7; 11·8 pounds of steam with 20·4 expansions for the normal compound having a ratio of 1 to 4 and 12·84 pounds of steam, with 33 expansion for the abnormal compound having a ratio of 1 to 7, all corrected for a steam pressure of 175 pounds per square inch.

The conclusion arrived at from those experiments is that normal cylinder ratios are more economical than abnormally large ratios, and it may be added that abnormally small ratios appear to be even less economical than the other.

Considerable light has been thrown on this subject by the expansion experiments on the Durham College and the Sibley College engines, and it is considered amply demonstrated, that the maximum degree of economy attainable at different total rates of expansion cannot be ascertained on the same engine having the same cylinder ratios. That, in short, the limits of pressure determines the proper relation of cylinder dimensions to attain this end, and that with our present knowledge theory provides as close an approximation to this relation as it is possible to estimate it.

APPENDIX.

The following is a numerical example of calculation for a three-cylinder triple expansion engine, having an initial absolute steam pressure of 150 lbs. per square inch; 1·3 expansions in each cylinder and 4 lbs. back pressure in the L.P. cylinder :—

$$\text{Assume } r = 9{\cdot}02\ ;\ \left(\frac{10}{r} - \frac{9}{r^{\frac{10}{9}}}\right) = {\cdot}3276\ ;\ \text{and } (1 - D) \text{ at } {\cdot}856.$$

$$r_1 = 1{\cdot}3 \quad \text{,,} \quad \text{,,} \quad = {\cdot}9683.$$

$$MP = \{(150 \times {\cdot}3276) - 4\}\ {\cdot}856 = 38{\cdot}64 \text{ lbs.}$$

$$MP_3 = \frac{38{\cdot}64}{3} = 12{\cdot}88 \text{ lbs.}$$

$$P_3 = \frac{12{\cdot}88 + 4}{{\cdot}9683} = 17{\cdot}433 \text{ lbs.}$$

$$\underline{R_3} = \left(\frac{150}{17{\cdot}433}\right)^{{\cdot}9} = \underline{6{\cdot}9384.}$$

And $6{\cdot}9384 \times 1{\cdot}3 = 9{\cdot}02$, showing that the assumed value of r is correct.

$$MP_1 = 12{\cdot}88 \times 6{\cdot}9384 = 89{\cdot}366 \text{ lbs.}$$

$$P_2 = (150 \times {\cdot}9683) - 89{\cdot}366 = 55{\cdot}879 \text{ lbs.}$$

$$\underline{R_2} = \left(\frac{150}{55{\cdot}879}\right)^{{\cdot}9} = \underline{2{\cdot}432.}$$

$$MP_2 = (55{\cdot}879 \times {\cdot}9683) - 17{\cdot}433 = 36{\cdot}677 \text{ lbs.}$$

When the mean pressures, multiplied by their respective cylinder ratios, are equal, then the calculation will be correct, thus :—

Proof :—

$$89{\cdot}366 \times 1{\cdot}0 = 89{\cdot}366.$$
$$36{\cdot}677 \times 2{\cdot}432 = 89{\cdot}200.$$
$$12{\cdot}88 \times 6{\cdot}9384 = 89{\cdot}366.$$

Although those are not absolutely alike, they are as nearly so as it is necessary to make them for all practical purposes.

Summary of calculation :—

R.	P_1.	MP_1.	Relative Loads.	Range of Temperature.
				Degs.
1·0	150	89·366	13·565	70
2·432	55·879	36·677	13·477	67·5
6·938	17·433	12·88	13·433	67·7

From which it will be seen that the relative loads and ranges of temperature are very nearly equal while securing equal powers.

The above calculation represents the method adopted in constructing the diagrams, but if it was intended for a given engine, the process would be modified by fixing the total number of expansions (r) and assuming the rate of expansion in each cylinder (r_1) instead.

DISCUSSION.

The SECRETARY read the following communication :—

DEAR MR. DUCKITT,

Mr. Andrews's paper is full of interest, and deals with a subject that has for a long time required proper treatment. Will Mr. Andrews explain why he has chosen the exponent $\frac{10}{9}$? It is not the adiabatic exponent for dry steam, although Rankine incorrectly gave that figure. This error is pointed out in Cotterill's *Steam Engine*, the mean value of the exponent being there given as 1·138; steam, however, is never dry, and $\frac{10}{9}$ may give results which agree closer with practice. Would Mr. Andrews use the same exponent for jacketed and unjacketed cylinders? In Mr. Willans's trials of a non-condensing unjacketed engine the exponent that appeared to give the best results was $\frac{7}{6}$ or 1·16.

What does Mr. Andrews consider the best terminal pressure for a given boiler pressure, and can it be expressed by any general law which gives either the terminal pressure or total ratio of expansion? Mr. Andrews uses an expression "diagram efficiency," which is sometimes given the name of "diagram factor." Is this best obtained by the formula—

$$E = \frac{\text{Actual MP reduced}}{\left\{ P_1\left(\frac{10}{r} \cdot \frac{9}{r^{\frac{10}{9}}}\right) \right\} - P_2}$$

as given by Mr. Andrews, or by the formula

$$E = \frac{\text{Actual MP reduced}}{\left\{ p_1 \frac{1 + \log r}{r} - p_3 \right\}},$$

where p_1 = boiler pressure absolute,
r = total ratio of expansion,
p_3 = back pressure absolute?

It is given by Prof. Unwin and several other authorities in the latter form.

Yours faithfully,

C. H. INNES.

The discussion was adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897–98.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, 26TH APRIL, 1898.

J. R. FOTHERGILL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on April 18th, which were approved by the members present, and signed by the Vice-President.

The VICE-PRESIDENT intimated that the President had been called away to Liverpool and could not attend the meeting.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897–98.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, 26TH APRIL, 1898.

J. R. FOTHERGILL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on April 18th, which were approved by the members present, and signed by the Vice-President.

The VICE-PRESIDENT intimated that the President had been called away to Liverpool and could not attend the meeting.

The discussion on Mr. James Andrews's paper on "Cylinder Ratios," was resumed.

Mr. A. L. MELLANBY read a paper on "The Effects of Different Arrangements of Crank Angles upon the Economy of Quadruple Expansion Engines."

DISCUSSION ON MR. JAMES ANDREWS'S PAPER ON "CYLINDER RATIOS."

Mr. R. L. GAINE, in opening the discussion on Mr. James Andrews's paper, said it was with considerable diffidence that he ventured to criticise any paper written by so able and experienced an engineer as he knew the writer of this paper to be; yet he ventured to do so, and he begged that they and he would take his remarks as being made in no spirit of captious criticism, but rather as the result of a genuine desire to get at what was a really correct method of calculation on a subject of such a very debatable nature as the one before them.

In the first place he would complain of this paper that to him it lacked lucidity. He might venture to say that in this respect it compared most unfavourably with, for example, the paper by Prof. Weighton on "The Normal Indicated Horse-Power of Marine Engines and Boilers," and one to be read before them that night by Mr. Mellanby, both of which he might quote as examples of papers of which—though the subject-matter was brimful of valuable information—there need not be the slightest difficulty in following through from beginning to end, and thereby more truly appreciating their value. He thought that a great deal more time might have been profitably spent by the writer in more carefully and fully describing the methods by which the very laboriously and carefully compiled diagrams at the end of the paper might be used; also, in the theoretical calculations worked out in the paper, important intermediate assumptions were omitted, and, if introduced from the private knowledge of the writer, yet even then did not justify the result obtained—most notably in the calculation which immediately follows Fig. 1 (page 201).

Further on, the writer gave the results obtained from two different quadruple expansion engines, having as their primary difference different back pressures in the low-pressure cylinder. These would seem to him to involve a contradiction. The writer said that the principal element in economical working is equality of temperature ranges, and assuredly the lower the low-pressure back pressure the better the system as a whole. Yet here they had a light small engine with a certain condenser more efficient than a larger one with a more efficient condenser. This would seem admissible on the face of it so far as economy alone was concerned (that was, assuming it to depend on equality of temperature ranges), but it was hardly credible that the initial loads and powers would be the same in each case.

In the beginning, the writer stated the intention of the paper as being to assist the designer who was brought suddenly face to face with the task of designing an engine differing entirely from anything he had had to do with before, say, of higher pressure and higher speed than he had been accustomed to; and when he (Mr. Gaine) read that he thought he had come upon something very valuable, but, going further on, he came against exactly the same stumbling blocks that they had to contend with in any other process of calculating cylinder ratios or cuts-off.

The writer said:—"These curves provide a simple means of determining the dimensions of cylinders in new designs to suit the circumstances of the case." Immediately above that he says, referring to his basis of calculation:—"The mean initial pressure absolute is the average between the beginning of the stroke and the point of cut-off, while the back pressure is the average over the whole stroke *as they are estimated to be obtained on the actual engine, according to the designer's practice.*" He (Mr Gaine) held that that was just the crux of the whole thing, viz., the correct estimation of the initial, and more particularly back pressures. In using these diagrams the designer had—apparently—to use his own constants, which could only be ascertained to be reliable from similar engines of similar speeds and pressures; and if that had to be introduced into the use of these diagrams, they were of no more value than the previously accepted methods were.

In referring to H.M.S. "Powerful," Mr. Andrews said:—"A question has been raised as to the proper dimensions of cylinders for above to get equal distribution of powers." He (Mr Gaine) did not know where this had been raised recently, probably in some technical journal, but on Mr Andrews's own showing he did not see the desirability of such equality.

And in view of Mr. Andrews's conclusions which follow, he failed to see how he could recommend such cylinder proportions as he did, even admitting, which he (Mr Gaine) did not, that equal cuts-off were most desirable in the economical use of steam.

The conclusions referred to were:—"That normal cylinder ratios are more economical than abnormally large ratios; and it may be added that abnormally small ratios appear to be even less economical than the other." There was no question that the actual sizes of the cylinders of H.M.S. "Powerful" produced a most uneconomical engine. He was guilty of no breach of privilege in saying so, as the necessary calculations to find that out could be made from the information that was accessible to anyone. If calculations were made it would be seen that the intermediate-pressure cylinder was much too large; indeed, the figures ran so curiously that it

would almost appear that the designer, in making his calculations, instead of halving a certain quantity, had doubled it. The sizes were:—45 inches, 70 inches, 76 inches, 76 inches.

In conclusion, he would express the opinion that Mr. Andrews had not reduced by this paper the calculation of cylinder ratios to a mechanical certainty, but had only indicated the direction in which a designer should go, leaving him to provide for himself the milestones by which his journey was to be regulated.

Mr. A. L. MELLANBY, B.Sc., thought it would hardly do to allow a paper like this to pass by without adequate discussion, although he felt he ought to apologise to the writer for speaking upon such an important subject with so little preparation. Perhaps if he set an example, it might induce others with a more specific knowledge to give their opinions. He thought the question of cylinder ratios must ever be one to attract attention. To the practical engineer it was important, because upon the proper proportioning of his cylinders depended, to a great extent, the economy of his engine, and a reputation for economical engines meant for him unlimited orders; to the more scientific man it was interesting chiefly on account of the difficulty attending its investigation. He must confess to being at first rather disappointed with the paper. As Mr. Gaine had said, he (Mr. Mellanby) also thought that from it he would find a method of saving himself a great deal of trouble, that he would only have to consult the diagrams, and from them be able to readily fix upon the best sizes of cylinders for any particular power and initial pressure. He now saw that what Mr. Andrews intended was, given certain initial conditions, and a certain amount of experience, here was an easy method of trial and error, by which the cylinder ratios to attain those conditions could be found. The question then resolved itself into the following:—Were these conditions the correct ones, and would their attainment produce the most economical engine? He quite agreed with the author when he said that having equal powers in each cylinder was not of much importance, and regretted that this should be in so many instances the chief engineer's standard of excellence. He had seen cases where the intermediate-pressure and low-pressure cylinders had been so linked up in trying to equalise the powers, that the revolutions were perceptibly less than when the powers in each cylinder were unequal, and yet the engineer had not perceived that what he had done was detrimental to the working of the engine. The question of initial loads was more important, and it would be found, he

thought, that equal initial loads gave a more even turning moment than equal powers. With the proposition of equal temperature ranges in each cylinder he did not agree. The temperature range in the high-pressure cylinder had a great deal of effect upon the consumption of the engine, as he had shown in the discussion upon Mr. Cummins's paper.* There he had given examples of an engine in which the point of cut-off in the high-pressure cylinder remain unchanged, and yet there was a very large increase in the consumption when the point of cut-off in the second cylinder was made later, and the volume of the second cylinder altered, thus increasing the temperature range in the high-pressure cylinder. The temperature ranges in the other cylinders could have no such effect upon the consumption. Incidentally they did have a slight effect, not recognised in text books, but this was only found by experiment. The result of the temperature ranges in the intermediate-pressure and low-pressure cylinders was to effect the areas of the cards from those cylinders, and it was found they could have large differences of range in these cylinders without having much effect upon the total mean pressure. From this it seemed to him to be certainly advisable to have the least temperature range in the high-pressure cylinder. Indeed, in a triple expansion engine, with normal proportions of cylinders and working at, say, 180 lbs. pressure, it would be difficult to avoid having a larger temperature range in the low-pressure than in the other cylinders.

As to having the expansions equal in each cylinder, that was, he thought, more an object of sentiment than of real value. The point of cut-off in each cylinder after the high-pressure one depended upon its ratio to that preceding, and it was upon getting this point of cut-off right that depended the economy of the engine. Then they came to the very practical consideration that marine engineers at least had very often to make the same size of engine serve for greatly differing horse-powers. He had seen the same engine with the valve gear designed to give a mean pressure of about 25 lbs. for one ship, and pressures up to about 29 lbs. for other ships. He gave this illustration to show that even if they had found what ratios were the best the question of cost would largely interfere with their being always applied.

Personally, he thought that the cylinders should be designed as follows :—The point of cut-off in each cylinder should never be earlier than half stroke, the range of temperature in the high-pressure cylinder should be as small as possible, always allowing a reasonable amount of receiver drop, and the initial loads should be fairly equal.

* See *Transactions North-East Coast Institution of Engineers and Shipbuilders*, vol. xiii., page 263.

He desired, in conclusion, to thank Mr. Andrews for his paper, and the manner in which he had placed the subject before them. If they did not agree with all that was said, yet, from the systematic manner in which the question was attacked at the commencement of the paper, it was easy to select the points upon which they differed, and to have what he thought ought to be one of the best features of these meetings, a good discussion.

Prof. R. L. WEIGHTON said this was a subject in which he was exceedingly interested. He had devoted more time to the consideration of this question than he should like to recall. Rather curiously, the writer of this paper was an old drawing office pupil of his own, both in Glasgow and on Tyneside. Mr. Andrews had communicated with him on this subject some time ago, saying that he was using methods somewhat modified and transposed, which he (Prof. Weighton) had published many years ago. That being so, he found that he could quite readily follow the main drift of this paper. At the same time he sympathised with Mr. Gaine, as he fancied it would be rather unintelligible in some parts to those not familiarised with the methods and symbols used. The subject was exceedingly complicated, and in all his consideration of the question, he had never been able to satisfy himself, even to a small extent, that any available method was satisfactory for determining the ratios between the cylinders of multiple expansion engines under given conditions and towards specified ends. There were so many unknown factors it must be approached by the method of trial and error. That was a method one was compelled to adopt in this case, and that was the method Mr. Andrews adopted. Certainly, he had simplified this very inconvenient and unwieldy method of trial and error by reason of the diagrams he had prepared, and from what he knew of Mr. Andrews he was certain they could take these diagrams as being very carefully worked out, and as being, at any rate, strictly in accordance with the formulæ given—he was sure of that. Now, the principal difficulty that surrounded this subject was of a two-fold character. The first source of difficulty might be called a mathematical one, taking its rise as it did from the difficulty of co-ordinating so many factors, some indeterminate, varying independently, and some varying with each other. They never had succeeded in evolving an equation containing only one unknown quantity, or even two unknown quantities. They had, therefore, to resort to the inconvenient "trial and error" method. The second difficulty was that even although they succeeded mathematically in evolving a correct system of rules, such as Mr.

Andrews had given on page 202, *i.e.*, suppose such rules were absolutely correct in theory, they were still quite worthless when applied to determine ratios for engines to be built and worked. And for this reason, that they contained no coefficients derived from experience. In fact, the whole subject must bristle with coefficients, because in no two cases, even of engines built from the same plans and patterns put into similar ships, would they get identical coefficients except by chance. This had been his experience at any rate. Still less might they expect to get identical coefficients with engines differing in type, that was to say, when dissimilar. Now, he thoroughly agreed with Mr. Andrews in what he said on page 199 about the desirability of systematising methods of proportioning engines. That was what he himself had been trying to do, but he had never solved the question satisfactorily. He had used similar methods to those in the paper for years, but he must confess he had often been obliged to have recourse to a method of "judicious guessing" multiplied by his own experience. Now, to speak generally, with himself personally, the difficulty was to say what ought to be said on this subject, to say what the nature of this subject warranted from its importance, and yet say it within reasonable compass. It was absolutely impossible, short of a long treatise, to deal with this matter even cursorily, and he would have to omit a great deal bearing upon individual parts of the paper. There were some parts of it not quite clear, but they always had this difficulty in papers. Some of the symbols were not quite justified. For instance, R_1 in the figure is not a ratio at all. If R_2 be the ratio between the cylinders, then R_1 is always unity. But if R_1 and R_2 be the volumes of the cylinders then the ratio of the cylinders is not R_2 but is $\frac{R_2}{R_1}$. Passing over a great many little things and statements which Mr. Andrews would, no doubt, justify were he present, let them enquire generally what was the object aimed at in the proportions of engines? First, their object might be to get the maximum power on given dimensions or given weights, or space occupied. In that case, they would choose as high a pressure as possible, and as small a number of total expansions as possible, and having chosen these it seemed to him a matter of comparatively small moment what particular ratios of cylinders were adopted. But the second object they might have in view, and this was the object which the writer aimed at, was to so fix their proportions that maximum economy would result irrespective of power in relation to weight. That was to say, their object here would be to secure that the minimum of water per horse-power was required, the boiler being left out

of the question. Now, there seemed to be a little confusion in the writer's mind about the difference between *desirability* and *economy*. He said on page 200: "When designing multiple cylinder engines, it is essential at the outset to determine certain conditions as a basis to work upon, and, generally speaking, the following ought to be fulfilled in order to secure the *most economical results*, alike from a practical and commercial point of view, viz.:—(*a*) The maximum loads on each piston; (*b*) range of temperature in each cylinder; (*c*) indicated horse-powers in each cylinder; (*d*) rate of expansion in each cylinder, should all be approximately equal." [The italics are the speaker's.] The writer says here that if the four conditions he specifies are fulfilled the *most economical results* will be secured. He (Prof. Weighton) agreed it was desirable (for several reasons which need not be specified) to fulfil those four conditions if they could; but it did not follow that if they were fulfilled maximum economy would necessarily result, for experiment had shown that it would not. In the first place, the formulæ or rules on page 202 would not, as they were there given, secure the fulfilment of the four conditions referred to in actual engines when working, and that principally because of the omission of coefficients derived from experience of similar engines to those in question. The coefficients—whatever might be their absolute value—would certainly not be identical in value as applied to estimate the mean pressure in each cylinder, and for this, as well as other reasons, the intended balance of power would be disturbed. Each one of the equations should be multiplied by a different coefficient, and he did not know why Mr. Andrews had omitted this. But, secondly, they would not secure maximum economy by merely employing an equal rate of expansion in each cylinder, even though the cylinder ratios were determined according to the author's methods. The most economical rate of expansion in each cylinder depended upon the ratio between the cylinders and upon that alone. Here was another most important point. The writer assumed that if they had equal rates of expansion in each cylinder they would secure, theoretically, all the other conditions he specifies, that was, equal maximum loads on pistons, equal temperature ranges, and equal powers. That that was the writer's opinion he knew from other sources; but that was not the case at all. Although they had equal rates of expansion in each cylinder they did not thereby secure equal ranges of temperature, indeed this was incompatible to some extent with the other three conditions. They would certainly get an approximation but not equality by a good deal: see the author's own tables, in which although $r_1 = r_2$ temperature ranges differ considerably. The

author admitted in a casual way that the results realised in the working of the engines would not agree with those predicted by application of the rules, but he said those variations could be easily corrected by slight adjustments of the links. But in his (Prof. Weighton's) opinion, it would require very serious linking up in many cases to secure the uniformity in conditions which were laid down. So serious might the linking up be, that they would incur great inefficiency due to the loss from linking up, which experiment showed might amount to a very great deal indeed. Therefore he (Prof. Weighton) did not think any system of linking up separately would secure a satisfactory result. It was not to be advised at all. He, for one, did not believe in making engines to link up separately. He knew of a case recently where the engineers in two sister ships had been having recourse to the separate linking up gear to such an extent as to seriously impair the economical working of both ships. As regards the relation between rate of expansion in each cylinder and economy of steam, it had been found in the engines which Mr. Mellanby would be dealing with in the next paper, that there was a certain ratio between the rate of expansion in any cylinder and the ratio of that cylinder to the preceding cylinder, which, when fulfilled, resulted in maximum economy in specified conditions. That ratio was indicated approximately in the following equation, namely :—

$$r_2 = \frac{R_2 + 1{\cdot}64}{2{\cdot}256},$$

the symbols were those used by Mr. Andrews. This was a deduction from a great many experiments which possibly might in the future form the subject of another paper; but he gave it now without further comment in order to justify his criticism. Now, if they fixed upon r_1, and then made r_2 equal to it, without reference to the possible value of R_2, they had no guarantee of maximum economy, at least so far as economy depended on r_2. Another point—it was assumed that equality of ratio of expansion in the cylinders would secure equality of maximum loads on the pistons. That was not so, except theoretically under two conditions, viz., first, when steam follows the hyperbolic law of expansion; and second, when the receivers were of *very* large capacity; only then would equality of maximum loads follow from equality of rates of expansion in each cylinder. In regard to the following reference to the College engine experiments (page 207) :—"Let it be *supposed that in a given engine the powers, initial loads, and temperatures are approximately equal when the rate of expansion in each cylinder is* 1·5. By reference to diagram, Fig. 4 (Plate XXIII.), it will be observed that increasing the number of expansions

increases the cylinder ratios; which, with constant cylinder ratios, is equivalent to increasing the relative power, initial load, and range of temperature in the low-pressure cylinder, and that the converse of this is the case if the number of expansions be reduced. On the other hand, reducing the steam pressure reduces the cylinder ratios; which, on the same engine, is equivalent to increasing the relative power, load, and range of temperature in the *high*-pressure cylinder, while reducing those elements in the *low*-pressure cylinder. In other words, varying the number of expansions or the steam pressure separately above or below that point at which approximately equal powers, loads, and temperatures have been obtained will have the effect of making those elements unequal, *and if it be granted that inequality in any of those factors reduce the economy* of an engine, then the point of maximum economy is easily located." [The italics are the speaker's.] First of all, in the experiments here referred to, when maximum economy was reached, the rates of expansion in each cylinder were not equal, neither were the initial loads, temperature ranges, or powers equal; and, secondly, instead of its being true that inequality of those factors reduced the economy, as a matter of fact economy was at its greatest when those factors were unequal. And it was difficult to see how mere change in cylinder ratios could alter this. It was not at all such a simple matter as this. The solution of the problem was exceedingly complicated. He (Prof. Weighton) for one was not prepared to say as yet on what maximum economy depended. It certainly did not depend upon the equality of those four factors. There was a sentence at the end of the above paragraph (page 208) he could not understand, viz.:—"The best results (referring to the College engines) should be obtained by a judicious combination of increasing the number of expansions with a reduction of the steam pressure, or conversely." As this stood, it appeared to him contradictory; and perhaps the author would explain. It seemed to him (Prof. Weighton) that really this paper was more *geometrical* than anything else. They could, by the application of geometry, and by taking sufficient trouble about it, deduce rules which would enable the theoretical boot-shaped figure of the expanded diagram to be divided into as many equal parts as there were cylinders, preserving the initial loads at the same time constant. This could be done by judicious allowances of receiver drops, etc., and so they might to some extent solve the matter geometrically. But this was entirely different from the economical point of view, the point of view of obtaining maximum economy so far as proportions of engines could obtain it. Moreover, it seemed to him they

could not solve this question satisfactorily, or, indeed, approach the solution of it at all, until they knew one particular factor which entered into all the calculations at the threshold of the subject, that was, the total expansion of the steam. What was the best total expansion to which to carry the steam under any given conditions as to boiler pressure, back pressure, etc. If they knew that they had got certain factors at once which cancel out to begin with, and they got their problem reduced to manageable dimensions. As it was, so many factors were indeterminate that they were landed in a confusion of formulæ, which were very apt to carry one away. He certainly thought Mr. Andrews had done very great service by bringing forward this subject, and he (Prof. Weighton) was sure that Mr. Andrews had thereby himself vastly advanced his own knowledge on the subject (there was nothing better than the writing a paper for getting up a subject). Still he thought Mr. Andrews would himself readily admit, on reconsideration, that the question was not by any means solved.

The SECRETARY read the following communication :—

11, GLENALMOND ROAD,
EGREMONT, CHESHIRE,
25*th April*, 1898.

DEAR MR. DUCKITT,

I beg to acknowledge, with thanks, due receipt of papers on "Cylinder Ratios" and "Crank Angles." With reference to the cylinder ratios of four-crank triple-expansion engines, the practical deduction, on reading and comparing the cases given, appears to be that there is everything to gain and nothing to lose in making the intermediate and each low-pressure cylinder of equal bore. One pattern would suffice for the three cylinders, and all four cylinders could be made to produce approximately equal powers with equal initial loads.

As to loss due to excessive ranges of temperature, it seems to me that with the high speeds of the present day, giving hundreds of changes per minute, the shorter time interval tends to reduce its importance considerably ; especially as the almost universal practice of fitting cylinder liners renders jacketing such a simple matter. By the way, I have often wondered why the suggestion of using oil for jacketing has not received more attention. Linseed oil at a temperature of 500° to 600° Fah., with a corresponding pressure of only 15 lbs. absolute, should, I consider, prove an ideal medium for conveying the needed heat to the expanding steam.

Yours faithfully,
J. H. GIBSON.

The VICE-PRESIDENT said he thought they must all have appreciated the very excellent discussion upon Mr. Andrews's paper. Although they might not all agree with the writer, yet he felt sure they would acknowledge the paper was not without interest and of value to the Institution, particularly in the discussion it had raised, and he conceived the writer would thoroughly appreciate the criticism which had taken place. They must not forget the subject was a most difficult one to treat, and the writer was entitled to the fullest consideration. The remarks by Prof. Weighton were most valuable and interesting. Gentlemen present who had the charge of engines must realise very distinctly what they had heard from Prof. Weighton. There were many points he had clearly and distinctly put before them, and which their own experience would fully bear out. He regretted Mr. Andrews was abroad, and therefore would have to reply in writing, but he had the greatest pleasure in asking them to accord him a vote of thanks in the usual way for his paper on "Cylinder Ratios."

The vote was given by acclamation.

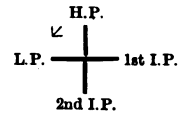
THE EFFECTS OF DIFFERENT ARRANGEMENTS OF CRANK ANGLES UPON THE ECONOMY OF QUADRUPLE EXPANSION ENGINES.

By A. L. MELLANBY, B.Sc.

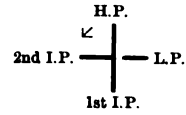
[Read before the Institution in Newcastle-upon-Tyne, on Tuesday, April 26th, 1898.]

In accordance with the wishes expressed by several members of this Institution, after Prof. Weighton had read his paper upon the experimental engines at the Durham College of Science, the writer now brings forward an account of another series of experiments carried out upon those engines.

The main object of the trials to be described was to find out whether it was the more economical to work quadruple expansion engines with the cranks H.P., 1st I.P., 2nd I.P., and L.P. at right angles to each other, following in the order given. thus :—



or with the cranks H.P. and 1st I.P. opposite each other, and at right angles to the 2nd I.P. and L.P. thus :—



From the manner in which the trials were carried out, and the way in which the results have been recorded, it is hoped that several points other than the main results may prove of some interest.

As the engines have been so recently and then so fully described, it would be out of place to take up the time of this meeting by presenting many details about them, consequently a very short account will be given, only sufficient to make the paper intelligible to those who are not familiar with that read by Prof. Weighton.

The engines are of the vertical marine type, with four cylinders and four cranks. The sizes of the cylinders used during these trials were :— High pressure, 7 inches ; 1st intermediate pressure, 10½ inches ; 2nd intermediate pressure, 15½ inches ; low pressure, 23 inches. The stroke of all the cylinders is 18 inches.

Measuring tanks are provided for determining the amount of feed-water used by the engine during a trial, and the amount of circulating water used may also be ascertained. The power of the engine is taken up by a hydraulic dynamometer of the type introduced by the late Dr. W. Froude, and to this is attached a specially designed apparatus which acts as a revolution counter and automatically records the brake horse-power exerted by the engine during a trial. By means of sluices the resistance of the dynamometer may be adjusted, thus allowing a large amount of control over the revolutions of the engine. The bolt holes in the crank shaft couplings have been so arranged that the different cranks may be set at varying angles with each other. It will be seen that this engine is admirably adapted for the set of experiments to be described, as a trial may be run with the cranks at any particular angles to each other, and then, without altering any other part of the engine, the bolts may be taken out of the couplings, the cranks adjusted to any other required angles, and coupled together ready for the next trial.

So far as the direct object of the investigation is concerned the only important results are those to be obtained with the highest boiler pressure available, 210 lbs., as it would not be advisable to work a quadruple expansion engine in actual practice at a much lower pressure. For this, it would have only been necessary to run one trial with the cranks in the one position, and another with the cranks in the second position, and compare the results obtained in the two cases.

After a considerable experience in engine trials, the writer has found that, for purposes of comparison, isolated trials, such as these would have been, are to be examined very critically, because from the nature of the experiments errors are liable to creep in, and with only one determination these may be lost sight of. This has, without doubt, much to do with the many conflicting results that are to be found of engine trials, and it is to be regretted that so many sweeping assertions have been made from the results of one or two trials. In order, then, to eliminate experimental error as far as possible, with each arrangement of crank angles a series of experiments was made with varying boiler pressure. As will be noticed later, this allows the results obtained to be put into a very simple diagrammatic form.

The first experiment was made with a boiler pressure of 210 lbs., a vacuum of 24 inches, and 140 revolutions per minute, as nearly as practicable. The cut-off in the high-pressure cylinder was at 12 inches of the stroke, giving 17·1 total expansions. Other experiments were then made at different boiler pressures, down to 70 lbs. The point

of cut-off in the high-pressure cylinder remained at 12 inches, the vacuum was kept at about 24 inches, by regulating the amount of circulating water, and the revolutions about 140 per minute, by changing the resistance of the dynamometer.

The relative positions of the cranks were then changed, and a similar set of trials made, the crank angles being the only factor that differed in the two series of trials; this gave experimental results of a fairly wide range to compare. The principal results determined are given in the table, and the economical relations of the two systems are shown in Fig. 1 (Plate XXVII.). To a base of brake horse-power are set off, as ordinates, the total pounds of water used by the engine per hour. An average line is then drawn through these points, and from this is calculated the water used per horse-power per hour, as shown by the curves. On the same base are set up ordinates of indicated horse-power, and an average line is drawn through the points there shown. It will be noticed that, for both sets of trials, the lines through the points of total water per hour and of indicated horse-power are practically straight lines. For the whole series of experiments the line of water per hour for the "cranks opposite" lies below that for the "cranks at right angles," showing the superiority in economy of the former arrangement over the latter. The line of indicated horse-power is also lower, pointing to a slightly higher mechanical efficiency of the "cranks opposite." It is to be noted that the results are in terms of the consumption per brake horse-power, the factor determining the real efficiency of an engine, although it will be seen that the water used per indicated horse-power for the "cranks opposite" is also slightly less than for the other arrangement. It ought to be explained that the line showing the total water used per hour is in reality a measure of the units of heat used per hour. This is obviously the more fair method of comparison, as the heat value of a pound of steam at 80 lbs. pressure is different to that of the same quantity at 210 lbs., and if pounds of water are only recorded, it is to the disadvantage of the lower pressures.

The method of heat units also takes account of variations in the hot-well temperature. These variations for different trials are unavoidable, as it is impossible to have the vacuum exactly the same in all cases, whilst at the same time the condensed water from the receivers, which passes into the hot well, is at a less temperature for the low-pressure trials than for those at the higher pressures. For each trial the number of heat units used by the engine, that is, the heat units given out by a pound of steam between the temperature of the high pressure steam chest and that of the hot well,

multiplied by the pounds of steam the engine uses per hour, were found. This gives necessarily a very large number, and to make the results more intelligible these numbers were each divided by the same quantity, namely, 1,111. This figure represents the heat units required to raise a pound of water from an absolute pressure of about 2 lbs. to steam at 210 lbs., so that the results obtained from dividing by this number may be considered to represent the pounds of water the engine would use, with a pressure of 210 lbs. absolute in the steam chest and a vacuum of 26 inches under the conditions named. In the diagram the results have been called pounds of water, but it should be remembered that they are in reality heat units, and, consequently, represent the true comparative economies of the different trials. The actual pounds of water used are given in the tables.

In Fig. 2 (Plate XXVIII.), which has been constructed from Fig. 1, the base line is taken as absolute pressures in the high-pressure steam chest, and the pounds of water used per indicated horse-power and per brake horse-power are drawn. The absolute pressures at which the experiments were run were first put down as ordinates on a diagram similar to Fig. 1, and, like the water used per hour, gave a straight line. This allows us without taking any great liberties to produce the curves, and, consequently, Fig. 2 shows the results to be expected with pressures up to 250 lbs. The noticeable point in this curve is the good results obtained with the low pressures and the consequently comparative small gain there seems to be likely to arise from higher pressures. It may be objected that the number of expansions (17·4) was not the most suitable for the higher pressures, and that with more expansions a better result would have been obtained at 250 lbs. pressure; but the same argument would hold good with respect to the lower pressures also, which would give better results with less expansions. If we consider 17·4 the best number for about 200 lbs., and from the paper read by Prof. Weighton this would appear to be nearly the case, then both below and above 200 lbs. we ought to get better results than are shown here. The curve of best results would probably be something like A B. Of course this is partly speculative, but it seems to point out that the gain to be expected from the use of high pressure has been often greatly exaggerated. This, however, is a point which requires further investigation, and it would be a very valuable research to find out the most economical number of expansions for different boiler pressures, and from these results to see what the actual gain in economy is likely to be from the use of high-pressure steam.

Figs. 3 and 5 (Plates XXIX. and XXX.) show the expanded indicator diagrams from the engines under the two conditions, with the boiler pressure at 210 lbs. The full curve shown is the adiabatic curve, calculated from the feed-water used per stroke, so that the area included between this curve, the vertical line, and the horizontal lines from any two pressures represents the full theoretical quantity of work that could be obtained from the steam working between those pressures. The effect that the difference in crank angles has upon the high-pressure exhaust line is very marked, and is worthy of notice, the line dropping gradually with the cranks opposite, and suddenly when they are at right angles; it may be that the difference this has upon the mean temperature of the cylinder walls in the two cases accounts for the slightly increased amount of water used per revolution when the cranks are at right angles.*

Figs. 4 and 6 (Plates XXIX. and XXX.) show the curves of effective pressure and turning moments, allowing for inertia effects, deduced from the indicator diagrams for both arrangements of cranks. There seems to be a notion abroad that the turning moment for a four-crank engine must be very uneven, especially for the arrangement we have called "cranks opposite," which some engineers assert will be almost as bad as that for a two-crank engine. The actual curve shows that this is not so, the turning moment being very steady throughout a revolution. For the "cranks at right angles" the minimum is 27 inch-tons, the maximum 38·7 inch-tons, and the mean value 31·7; with the "cranks opposite" the minimum is 26·5 inch-tons, the maximum 38·4 inch-tons, and the mean 31·3. There is practically no difference between the minimum and maximum values for the two cases, although the "cranks opposite" seems on the whole to have the steadier turning moment.

The general conclusion to be drawn seems to be that the arrangement with the "cranks opposite" is the better of the two, both as regards economy and steadiness of working; and it is hoped that these experiments may help engine builders who are contemplating building quadruple engines to determine which arrangement of cranks they should adopt.

---

* See paper by Callendar and Nicolson on "The Law of Condensation of Steam." *Proceedings of the Institution of Civil Engineers*, vol. cxxxii., part 2.

QUADRUPLE EXPANSION TRIALS, CRANKS THUS L. — H. — I_1. — I_2.

Boiler Pressure above Atmosphere.	H.-P. Steam Chest Pressure above Atmosphere.	Hot-well Temperature.	Vacuum.	Barometer.	Revolutions per Minute.	Total Water Used per Hour.	I.H.-P.	B.H.-P.	B.H.-P. / I.H.-P.	Mean Pressure Reduced to L.-P. Cylinders.	Pounds of Water Used per Hour per		Heat Units Used per Minute per		I.H.-P. at 140 Revolutions.	B.H.-P. at 140 Revolutions.	Water Used per Hour at 210 lbs. 26 ins. Vacuum and 140 Revolutions.
											I.H.-P.	B.H.-P.	I.H.-P.	B.H.-P.			
Lbs.	Lbs.		Inches.	Inches.		Lbs.											
210·6	200·7	141·3	24·09	29·52	140·3	2,025	158·4	140·7	0·888	30·08	12·77	14·39	232	262	157·9	139·9	1,982
190·0	183·5	139·9	24·16	29·52	136·3	1,829	140·8	125·2	0·889	27·54	12·98	14·61	236	265	144·6	128·5	1,842
170·3	162·4	139·1	23·92	29·32	141·4	1,683	127·4	113·4	0·889	24·01	13·21	14·83	239	269	126	112·3	1,631
150·0	143·0	140·7	24·26	29·75	140·9	1,534	114·5	96·7	0·844	21·68	13·39	15·85	242	286	113·8	96·1	1,486
130·0	124·0	137·8	24·40	29·75	137·2	1,345	92·8	80·7	0·869	18·01	14·49	16·66	262	301	94·5	82·4	1,338
110·0	107·0	138·1	24·25	29·75	140·2	1,206	82·6	68·6	0·831	15·70	14·51	17·56	263	316	82·4	68·5	1,170
90·0	87·4	136·5	24·27	29·80	139·2	1,023	64·9	53·6	0·827	12·43	15·76	19·07	283	342	65·2	53·9	998
70·0	69·4	134·8	24·21	29·80	142·3	882	53·1	39·5	0·744	9·93	16·60	22·30	297	399	52·1	38·9	839

QUADRUPLE EXPANSION TRIALS, CRANKS THUS I_2. — H. — L. — I_1.

209·1	200·0	142·6	24·17	29·77	138·2	1,969	157·0	140·3	0·894	30·29	12·53	14·03	227	255	159·1	142·1	1,955
190·0	185·3	141·6	24·49	30·1	142·5	1,891	144·9	131·6	0·907	27·11	13·04	14·36	237	261	142·3	129·3	1,819
170·0	163·1	138·7	24·32	29·42	143·1	1,609	128·9	116·0	0·900	23·98	13·25	14·72	240	267	125·9	113·5	1,638
150·0	146·7	140·1	24·52	30·1	143·7	1,573	118·2	103·0	0·871	21·91	13·31	15·27	241	276	115·0	100·3	1,496
130·0	125·6	135·7	24·47	29·96	140·1	1,334	98·3	85·4	0·868	18·69	13·56	15·61	245	283	98·1	85·3	1,302
90·0	87·0	130·3	24·53	29·82	145·7	1,049	69·9	56·1	0·802	12·80	14·99	18·69	271	337	67·2	53·9	983

DISCUSSION.

Prof. WEIGHTON said he was personally obliged to Mr. Mellanby, and that for two reasons, because he had consented to undertake the preparation of this paper and because of the excellent and careful manner in which he had carried out the work undertaken. The amount of work involved in the preparation, especially of the crank effort diagrams, must have been very great indeed. As regarded the broad, general lesson to be learnt from these trials as here recorded, there was absolutely no doubt in his mind. At first he (Prof. Weighton) was very sceptical of the results obtained, as Mr. Mellanby knew, and insisted upon the trials being repeated, to make sure there was no error. They certainly got some abnormalities and irregularities which they could not explain, but that always occurred with experiments. In order to make certain of no mistake, he had, since the date of Mr. Mellanby's trials made fresh experiments, and these fresh experiments confirmed exactly the results given here, although these latter trials were made with a different high-pressure cylinder, and with a new slide valve, on which he was experimenting. The results, at full power, were exactly the same as those in the paper, and he therefore considered they might be taken as absolutely correct for the circumstances in which they were made. There was, he thought, no difference appreciable in the turning moments of the two arrangements. The one was equally as good as the other. He at first thought like those to whom Mr. Mellanby referred, that probably cranks placed right opposite would not be quite so good as cranks at right angles; but they had turned out to be quite the same, at least under ordinary conditions of cuts-off such as were likely to be used in marine engines. No doubt, if cuts-off were to vary very much there would be some difference in the results. While, however, there seemed no difference in turning effort there *was* a difference in economy. If they compared in Fig. 1 (Plate XXVII.) the curves of "water per indicated horse-power" and "water per brake horse-power," it would be found that the difference between the two former was just one-half that between the two latter. That is, the saving in water per indicated horse-power was 1½ per cent., while the saving per brake horse-power was 3 per cent. The straight lines of indicated horse-power on same figure show the secret of the former saving—higher mechanical efficiency; that was to say, to attain a given brake power a higher indicated power must be attained with cranks at right angles than with cranks opposite. The other 1½ per cent. must therefore be due to an increased efficiency of

steam in the case of opposite cranks as compared with right-angle cranks. How did that come about? He thought it could be explained in this way: the increased efficiency of the mechanism when the cranks were opposite seemed to him to be due to the fact that with cranks right opposite the crank shaft would, so to speak, be floating more or less, and there would therefore be a minimum of pressure upon the main bearings. In other words, there was a couple always tending to turn two contiguous cranks, the forces never acting in the same direction and not pressing the shaft into the bearings; whereas, with cranks at right angles, both pistons acted during at least one-half of their stroke in the same direction, thus pressing the shaft upon its bearings. Therefore, on the whole, he thought in the latter case there would be increased friction loss on the main bearings. Secondly, how could this changing of cranks affect efficiency of the steam? This was a question which puzzled him for some time, till it occurred to him to lay down a diagram showing the variation of virtual receiver capacity in the two cases. (See diagram, Plate XXXI.). From this diagram it was clear that in the case of right-angle cranks the high-pressure cylinder was subjected throughout its whole length to the minimum temperature of the receiver, whereas in the case of opposite cranks, only from one-third to one-half of its length was subjected to this minimum temperature, whatever it might amount to. In this latter case, therefore, one would expect rather less condensation at admission, and if initial condensation means loss, then this consideration would explain at least some part, if not all, of the difference in steam-efficiency shown in these results. What he had said about the high-pressure cylinder referred also, of course, to the I_2P cylinder. In conclusion, he (Prof. Weighton) said he had made a calculation, by taking the price of coal at about £1 a ton, that they would save about 10s. per thousand effective horse-power per steaming day by using the cranks opposite as compared with right angles.

Mr. J. K. Sinton asked how they were going to get the engines started with the cranks right opposite, and how could they be reversed?

Prof. Weighton said there was no difficulty at all—rather easier started the one way than the other with four cranks.

Mr. J. K. Sinton quite agreed they could with quadruple engines, but they had triple expansion and compounds to deal with; as regarded the compound he had had them at various angles, but he was of opinion that

an angle of 90 degrees was the best and most economical. They were the most easily handled in working out of and into port. It was one thing working vessels at sea on a long voyage, it was another thing after having run fifty or sixty days to bring them into port without incurring damage. They had heard a great deal of late about the incapacity of engineers as regarded bringing vessels into port. He thought the engine builders were much to be blamed, as they evidently had not taken into consideration the matter of working the engines in narrow waters and rivers when setting the crank angles.

Prof. WEIGHTON said his friend had entirely misinterpreted the intention of the paper. It referred alone to four-crank engines, they could not put the cranks opposite in two-crank. For land purposes there was no reason why two-crank compounds, with a fly wheel, should not have cranks opposite, indeed it was done every day in small engines.

The VICE-PRESIDENT said he was sure they would agree with him that they had heard a most interesting paper; not only interesting in the information given them, but more especially in the fact that it was not hypothetical; the whole of it consisted of facts taken from the experimental engine at the Durham College of Science, Newcastle, and which were of the utmost value. He should just like in particular to refer to page 231, where the writer spoke of the turning moment of the cranks. There was no doubt many of them would have heard within the last two or three years a great deal said about the turning moment of the cranks, and that four cranks were nothing more or less than the multiple of the evil of the turning moment of the two cranks of the compound engines. He must say he was surprised at the results obtained, and he believed many like himself had held very different views. He thought this was very strong evidence of the great value of an experimental engine like the one at the College, and must be satisfactory to the donors of the engine.

The discussion was adjourned, and the meeting dissolved.

COMMUNICATION FROM MR. GEORGE DYKES ON "A RELIABLE METHOD OF OBTAINING THE NECESSARY DISPLACEMENT AND CENTRE OF BUOYANCY OF SHIPS." *

HAMBURG,
March, 1898.

DEAR MR. DUCKITT,

In Mr. Hogg's paper on "The Comparison and Construction of Ship's Lines," he describes a very useful method for drawing a curve of areas, representing the volume of displacement of the ship, but as these curves are of a similar form and for a certain type of ship, they may not agree with the ideas of other designers as to what a ship should be like.

It may interest the members of this Institution to hear of an old and very reliable method of obtaining the necessary displacement and centre of buoyancy longitudinally, which will in no way interfere with the designer's freedom. As will be seen by reference to Plates XXXII. and XXXIII., any desired coefficient can easily be found, and at the same time the designer is not limited to any definite form, because he can make his curve of areas to suit his ideas.

Plate XXXII. shows the form of different figures enclosing an area denoted by the coefficients marked between the two diagrams, the scales at the foot of the plate show the variation in the height of the centre of gravity for the different figures.

Plate XXXIII. In constructing the diagram for curves of areas shown in this plate, Fig. 1 is a rectangle divided into a number of trapeziums equal to an area denoted by the coefficient along the top of the figure; the centres of gravity above the base are calculated for each trapezium, and the ratio of this height to the total height is shown in Fig. 3.

Fig. 2 (Plate XXXIII.) is the rectangle divided vertically along one side into trapeziums equal in area to those in Fig. 1, but the height of the centres of gravity for these are a smaller ratio than those in Fig. 1, as will be seen by reference to Fig. 3. This Fig. 3 is applicable to all cases, giving the height of the centre of gravity in any area of a given coefficient, and the maximum variation the centre of gravity has in all curves of arc form.

* Alluded to by Mr. Robert Thompson on page 197.

Fig. 4 (Plate XXXIII.) shows the latitude and Fig. 6 (Plate XXXIII.) its application. In Figs. 4 and 6 all the trapeziums are equal to a coefficient of ·70.

Fig. 5 (Plate XXXIII.) is an example showing the construction of a curve of areas for the after body of a ship, the following particulars being given :—

Length on water-line...	...	270 feet.
Beam moulded ...	...	39 „
Draught from top of keel	...	16 „
Area of midship section	...	600 square feet.
Cylindrical coefficient	...	·70.
Centre of buoyancy ...	...	2·70 forward of midship station.
Displacement in tons...	...	3,240.

In Fig. 5— L = half length on water-line.
D = area of midship section.

Draw a rectangle to any convenient scale, make the length equal to half water-line, and the height equal to the area of the midship section. Draw the coefficient line EF, making the length X equal to—

$$\frac{X \times D}{2} = \cdot 3(L \times D) \therefore X = \cdot 6L,$$

$$\text{and } \frac{Y \times L}{2} = \cdot 3(L \times D) \therefore Y = \cdot 6D,$$

and join EF.

A trapezium can now be drawn, keeping the point C in any position along EF, and the area will be equal to ·70 of the rectangle. The position of the point C allows the designer to make what he may think the most suitable type of curve.

Having drawn in the trapezium A in Fig. 5, it can quickly be altered to A1, Fig. 5, or as more clearly shown by the dotted lines in Fig. 6 (as the dotted line is a closer approximation to a curve). Having done this, it is easy to draw in the curve representing the volume of displacement in the after body. The forward body will be the same as the after body, unless the centre of buoyancy is required to be away from the midship station.

If it is required to place the centre of buoyancy in any other position, say 2·70 forward of midship station, then from Fig. 5 the ratio of $\frac{Z}{X} =$ ·90, and referring to Fig. 3 it will be found that the height of the centre of gravity for ·70 coefficient and ·90 ratio is equal to ·420 of D. Mark this height on the midship station in Fig. 5, and set off in the direction

of the fore body the position of the centre of buoyancy in per cent. of the length, say $\frac{2 \cdot 7}{270} = 1$ per cent. of water-line length and 2 per cent. of L, through this point and the intersection of the midship station with the base, draw a new station and make the other stations parallel to it; where the curve of areas, B (Fig. 5), intersects the square stations, project these points on to the new angular stations and draw in the curve B_1, this curve will be finer than the curve B in the after body, and fuller in the forward body, and the centre of buoyancy will be 2·70 forward of midship.

This method will be found to give a very close approximation to any curve of area required.

I have to express my best thanks to Robert Thompson, Esq., for his kindly undertaking the preparation of the above drawings, etc.

Yours faithfully,

GEORGE DYKES.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTEENTH SESSION, 1897-98.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, MAY 13TH, 1898.

COL. HENRY F. SWAN, J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on April 26th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. R. H. Muir and Jas. Thomson to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Alexander, Francis H., Ship Draughtsman, 42, Percy Park, Tynemouth.

Mechan, Henry, Engineer, c/o Messrs. Mechan & Sons, Cranstonhill, Glasgow.

Spark, H. King, Engineer, Messrs. Anti-Attrition Metal Co., Ltd., Emerson Street, Southwark, London, S.E.

Thompson, Arthur E., Engineer, 19, The Crescent, Gateshead-on-Tyne.

Waller, Thos. Naunton, Engineer, 10, Holly Avenue, Jesmond, Newcastle-upon-Tyne.

GRADUATES TO MEMBERS.

Maslen, Frank E., Engineer, 14, Belsize Park Gardens, Hampstead, London, N.W.

Nichol, Bryce G., Engineer Draughtsman, 84, Third Avenue, Heaton, Newcastle-upon-Tyne.

ASSOCIATE.

Winter, Edward G., Accountant, 10, Lincoln Terrace, Gateshead-on-Tyne.

GRADUATES.

London, W. J. A., Engineer Draughtsman, 12, Victoria Square, Jesmond, Newcastle-upon-Tyne.

Smith, F. Henry, Ship Draughtsman, c/o Messrs. Laird Bros., Birkenhead Iron Works, Birkenhead.

The SECRETARY read Mr. A. E. Long's reply to the discussion on his paper on "Some Points of Interest in the Designing of Cargo Steamers." Also Mr. James Andrews's reply to the discussion on his paper on "Cylinder Ratios."

The discussion on Mr. A. L. Mellanby's paper on "The Effects of Different Arrangements of Crank Angles upon the Economy of Quadruple Expansion Engines" was resumed and concluded.

Closing Business.

o
n
a-
les
ank
tical
s for
most
proved
ignored
tation to

l with the
were given
te adapted to
, but they did

the very kind

d to Mr. Long
sure they would
his paper.

relatively less important in very large vessels at ordinary mercantile speeds; in fact, in the coming race of ships, 1,000 feet long or so, they—or their successors—might very closely approach the square-ended box, as far as smooth water trials were concerned. Probably the limit would be found in the actual sea-going performances. In vessels of moderate size, as stated in the paper, they had already, he believed, overstepped the useful limit of coefficient. The vessel of ·815 coefficient given by Mr. De Rusett was probably very large—approaching 500 feet in length, for which, of course, 11 knots was a relatively moderate speed; if, however, they built a vessel of, say, 300 feet on the same lines, the result might be very poor.

Mr. Hogg made his remarks so brief that they bore a decidedly oracular aspect. He gave 412 feet 6 inches by 50 feet, and 400 feet by 52 feet 10 inches, instead of the figures given in the paper, but did not confide to them how these dimensions were arrived at. By a somewhat extensive course of reading between the lines they might guess that they were obtained by constructing block ships of equal angle of entrance. It might be useful to consider what would occur if Mr. Hogg offered these alternative proposals to the average shipowner in the form of tenders. The man of money would most likely first note that the broad vessel was slightly the cheapest, then a little simple multiplication would show him that, taken as a rectangular box, she was also the largest. On these grounds alone the shipowner would probably select the broad design, and with a not unnatural desire to get the maximum value for his money, would instruct Mr. Hogg to use the coefficient of the longer boat. If the latter declined on scientific grounds to build such a vessel, there were many builders ready to build to any coefficient that might be asked for short of 1·00. He sympathised with Mr. Hogg in his dislike to the block coefficient in much the same way as he did with those persons who wished that all the world was good; but, practically, the world was not all good, and shipowners used block coefficients or none at all. Possibly a pleasing feature of the millennium might be the shipowners' study of tenders by the light of formidable scientific data; but they had not yet reached that stage, so the block coefficient was used intentionally in the paper. Mr. Hogg appeared to think that there would be a saving in cost of machinery due to the longer vessel requiring less power. Practically, when alternative proposals, such as those given in the paper, were made the machinery tendered for would be identical, as almost every engineering establishment had stock sizes of engines, and did not make new drawings, patterns, etc., for every small variation in power possible in theory. This

slight difference between theory and practice, which Mr. Hogg might have overlooked, would account for the absence of any notice of power in this part of the paper.

Mr. Alexander had favoured them with a very interesting maiden speech, which had all the more value as the speaker had had some practical sea-going experience. As regarded what might be called the millinery part, the use or otherwise of dotted lines in the diagrams, unless these erroneously represented the visible or hidden parts of a solid, they were generally left to the fancy of the author. If the present selection had in any way offended Mr. Alexander's susceptibilities the writer was sorry. Mr. Alexander drew attention to some points of interest which had been wholly omitted. He had possibly not read the title of the paper as carefully as he apparently had the paper itself. The word "some" was inserted advisedly, as the writer was well aware that a paper dealing with all points would have more nearly reached in length twenty hours than twenty minutes. If he had drawn Mr. Alexander's attention to possible subjects for a paper he would have doubtless done the Institution a service. Mr. Alexander's remarks about the difference between sea-going and measured mile results illustrated very well one of the puzzles which the ship designer met with. Given an admirable form for tank experiments, or smooth water trials, would she be a success in practical work? The Atlantic liners were well known examples of good forms for sea work, which might be easily beaten in a tank. Some of the most successful of the torpedo boat destroyers might also have been improved upon from the smooth water trial point of view, if their designers ignored practical sea-going requirements. In them, of course, the temptation to do wrong was almost irresistible.

He was pleased to find that Mr. Robt. Thompson agreed with the objections raised to coefficients beyond ·8. Some instances were given in the paper in which Lloyd's rules did not appear to be quite adapted to latter-day requirements, and there were a good many more, but they did not quite come within the scope of the paper.

In conclusion, he begged to thank the members for the very kind way in which they had received this paper.

The PRESIDENT said they were all very much obliged to Mr. Long for the valuable paper he had contributed, and he was sure they would authorise him to accord to Mr. Long a vote of thanks for his paper.

The proposal was received with acclamation.

MR. JAMES ANDREWS'S REPLY TO THE DISCUSSION ON HIS PAPER ON "CYLINDER RATIOS."

The SECRETARY read the following reply from Mr. Andrews to the discussion on his paper on "Cylinder Ratios":—

DEAR MR. DUCKITT,

In reply to the discussion on my paper, I will endeavour to answer the various criticisms in the order in which they have been reported to me. Mr. Gaine, in opening the discussion, complains of a want of lucidity in the paper, which, of course, is as likely to be the fault of the reader as the fault of the writer, and from the remainder of his criticism I am disposed to think that the former is the case. Mr. Gaine's first difficulty is that he does not understand how to use the diagrams. When it is considered that a paper must be read within a limited time, it seems a waste of time to give the reason and describe the method of construction, then to describe the reverse process. However, I will now state a case. Given a quadruple expansion engine having a mean initial pressure of 190 lbs. absolute, low-pressure back-pressure of 4 lbs., and a terminal pressure of 8 lbs. absolute. The relation between the actual terminal pressure and the diagram terminal pressure depends upon the designer's practice, but is not of very much importance, say about 10 per cent. difference, or nearly 9 lbs. On Fig. 4 (Plate XXIII.) we find for 9 lbs. terminal pressure and 190 lbs. initial pressure, the cylinder ratios to be 2·03, 4·48, and 11·07, with a rate of expansion in each cylinder of 1·42, or practically 70 per cent. cut-off. The diagram mean-pressure reduced to the low-pressure cylinder is 33·7 lbs., which, multiplied by a coefficient, also determined by the designer's experience, say ·9, gives 30·3 lbs. actual mean pressure reduced to the low-pressure cylinder. It is a matter of choice whether the terminal pressure, total rate of expansion, or rate of expansion in each cylinder be determined, the remaining factors will be found on the diagrams. There is no possible means of getting over the element of experience in determining the coefficients referred to, nor is there any serious difficulty in determining them as Mr. Gaine would appear to think, and any method or diagram which pretends to meet all cases without them, would be worse than useless. The next point raised by Mr. Gaine has reference to the effect of the low-pressure back-pressure upon the cylinder ratios. In this connection he seems to associate a small cylinder ratio with a high efficiency, although why I am at a loss to understand, because there is certainly no reference to the relative economy of the two cases mentioned in the

paper. There is also some confusion in his mind with regard to the equality of temperature ranges, but to which I will refer later on.

The question anent the "Powerful's" cylinder dimensions was raised by Mr. Gibson during last session.* I have not recommended any cylinder ratios, although I have given cylinder ratios which would produce certain results. In short, Mr. Gaine's remarks are largely composed of misunderstandings, perverted quotations, and unwarranted opinions, which I can only account for by a careless perusal of the paper.

Mr. Mellanby states the importance to the engineer of properly determining cylinder ratios, at once clearly and concisely, and with which I fully concur. With the explanation of the diagrams which I have already given, coupled with a very little experience, he may find that they will not only save him a great deal of trouble, but that very nearly, if not absolutely, the best size of cylinders for any given power and initial pressure can be fixed in a very few minutes. The principal point raised by Mr. Mellanby, however, has reference to the range of temperature in each cylinder. In condition (*b*), page 200 of the paper, it is stated that "the temperature range in each cylinder should be as low as possible and probably equal." Now, the probability here implies a doubt which Mr. Mellanby does not entertain, but I would submit that it is a reasonable doubt, because it is not a point upon which one may express a dogmatic opinion. It may be that the temperature range in the first cylinder should be least, but certainly Mr. Mellanby has not yet shown it to be so. What he has shown is that it is more economical to expand steam in three stages than in two, and that in three-stage expansion engines there are good and bad subdivisions of the three stages, but what part the temperature range in the high-pressure cylinder played in the ultimate result apart from other causes he has not told us. As a matter of fact, the most economical engines which I can recall to mind at the moment are directly opposed to Mr. Mellanby's theory, inasmuch that the highest temperature range is in the first cylinder and the lowest in the last. Notably, the cotton mill compound engine referred to in Thurston and Brinsmead's paper,† in which the temperature ranges are, high-pressure 110 degs., low-pressure 91 degs. Fahr.; the Milwaukee triple expansion pumping engine,‡ in which they are, high-pressure 86 degs., intermediate-pressure 59 degs., and low-pressure 56 degs. Fahr., and, finally, the Sibley College triple expansion engine, given on page 209 of the paper.

As Prof. Weighton had told them, I received my early drawing office

* *Transactions*, vol. xiii., page 216. † See *Industries and Iron*, vol. xxiv., page 24

‡ See *Transactions* of Institution, vol. viii., page 73.

training under his direction, and it was due to what I believe to be his first paper on this subject, and the absorbing interest he took in it at that time, which led me to follow his example. I have followed his methods ever since, have worked out and tabulated coefficients by the hundreds, and am therefore in a position to appreciate his remarks anent their inconsistency. It was, in fact, their inconsistency which forced the writer, for the purpose of calculating cylinder ratios, to abandon them at the intermediate stages, and by comparing the cylinder ratios so calculated with actual engines, to see whether the actual cylinder ratios or subdivisions of expansions did not affect the coefficients in question. A few of those comparisons with actual engines of different types are given on page 205, which show that in every case, whether the actual cylinder ratios be larger or smaller than those calculated, the latter indicate the direction of an improvement, and from which it may be inferred that if cylinder ratios were systematically determined on this basis the coefficients for receiver and mean pressures in each cylinder would be much more uniform. Why that should be so was partly due to the percentage of water as compared with steam present in each cylinder, which was found to vary in a certain way with the cylinder ratios and the rate of expansion in each cylinder. When Prof. Weighton states that "in no two cases, even of engines built from the same plans and patterns put into similar ships, would they get identical coefficients except by chance." Presumably he refers to workmanship or the quality of the steam supplied from the boiler, which are questions outside the scope of the present paper.

With regard to the symbols, R_1 and R_2 are correctly described on page 201 as representing relative volumes, and not cylinder ratios or cylinder volumes, as mentioned by Prof. Weighton. Referring to the question of economy, Prof. Weighton quotes the four conditions given on page 200, which "ought to be fulfilled in order to secure the most economical results," etc., and credits me with a little confusion in the mind "about the difference between desirability and economy." Now, I did not know that these two words had any relation to each other at all, but I can draw a very broad distinction between *ought* and *must*. The former is the word used, and since it implies a desirability—not a certainty—there is no confusion, but in reality an agreement with him. A little further on he tells us that in the Durham College experiments none of the elements were equal when maximum economy was reached, as if that was a proof that they need not be equal. I would say, on the contrary, that it was very strong evidence of the cylinder ratios being bad, and when coupled to the other published

information, that it was not the most economical quadruple expansion engine that could be made. Again, Prof. Weighton says :—"The writer assumed that if they had equal rates of expansion in each cylinder they would secure, theoretically, all the other conditions he specifies, that was, equal maximum loads on pistons, equal temperature ranges, and equal powers." It is scarcely conceivable that anyone could make such an assumption and at the same time publish Diagrams 5, 6, and 7 (Plates XXIV., XXV., and XXVI.) in the same paper, because they would condemn it at once. Neither equal temperatures nor equal maximum loads would be secured but what is assumed ; what is said in fact on page 207 is, that there is an "approximate coincidence," which Prof. Weighton evidently agrees with. The explanation of the sentence (page 208): "The best results should be obtained by a judicious combination of increasing the number of expansions with a reduction of the steam pressure or conversely," was that increasing the number of expansions has the effect of increasing the relative power, initial load, and temperature range in the low-pressure cylinder ; while reducing the steam pressure has the effect of increasing the same elements in the high-pressure cylinder, so that a combination of the two would have the effect of maintaining an approximate equality which, it was considered, might produce the best results.

In reply to Mr. Innes's question, I can only say that I have used the exponent $\frac{10}{9}$ because it agrees with marine engine practice as well as any other and is in most general use. So long as there is free expansion in the intermediate receivers of multiple cylinder engines there can be no fixed exponent, because the consequent drying of the steam alters the exponent at each stage.

As Prof. Weighton pointed out in his opening remarks, the subject was an exceedingly complicated one, it is by no means solved, but it is only by the systematic treatment of it that we can ever hope to advance, and if the paper, with its accompanying discussion, has attained this end in some measure the object of the writer will have been fulfilled.

In conclusion, I have much pleasure in acknowledging the valuable assistance rendered to me by Messrs. Suijver and Hamilton in the construction of the diagrams accompanying the paper.

Yours faithfully, JAMES ANDREWS.

The PRESIDENT said they were all very much indebted to Mr. Andrews, who was apparently living in Holland, for his paper and the written remarks on the discussion. He had no doubt they would accord him a hearty vote of thanks. The vote was carried with acclamation.

DISCUSSION ON MR. A. L. MELLANBY'S PAPER ON "THE EFFECTS OF DIFFERENT ARRANGEMENTS OF CRANK ANGLES UPON THE ECONOMY OF QUADRUPLE EXPANSION ENGINES."

Mr. E. GRIFFITH, in further discussion upon Mr. Mellanby's paper, said there was one question he would like to ask arising out of the paper, and it was this: It seemed to him that this controversy dealt with a very old question which was settled the other way twenty or thirty years ago in respect to the two-cylinder compound engine. These were at first of the crank-opposite type, but it came to be finally believed that cranks at right angles were more economical than cranks opposite each other, quite independently of the other comparative merits of the two types. Now, these experiments described by Mr. Mellanby were simply the same thing over again, for this was a comparison between a series of compounds with cranks at right angles and a series mostly with cranks opposite each other, the result being in favour of the latter. He would like to know how Mr Mellanby accounted for this. Did he think the old engineers were wrong in this matter? As a very large receiver was considered necessary for the best results from the old compound with cranks at right angles, he had thought that perhaps the receivers of the College engine were too small to give that arrangement of cranks a fair trial, but he was told by Prof. Weighton that actually the receivers were very large.

Prof. WEIGHTON—The high pressure only.

Mr. GRIFFITH suggested that possibly if all the receivers had been very large, the results of these trials would have been different, and more in accordance with the prevalent opinion in the days of the two-crank compound.

Mr. A. L. MELLANBY, in reply to the discussion, said that he felt very much obliged to Mr. Fothergill and Prof. Weighton for the kind remarks they had made at the previous meeting, and to the members generally for the manner in which they had received the paper. He was sure they would all be glad to learn that the confirmatory tests made by Prof. Weighton showed results similar to those given in the paper. The diagram (Plate XXXI.) presented by Prof. Weighton was extremely interesting, and when studied in conjunction with the expanded cards afforded a ready explanation of the difference in the exhaust lines in the two cases. With regard to the question of initial condensation, it would

be noticed that in the case of the cranks at right angles the lowest temperature in the high-pressure cylinder occurred at the end of the stroke when the piston was moving slowly. The consequence was that not only was the greater amount of surface exposed to the low temperature, as mentioned by Prof. Weighton, but the time of exposure was longer than in the case of cranks opposite, when the lowest temperature was attained in the middle of the stroke. He thought that these two circumstances combined would result in the mean temperature of the cylinder walls being the lower in the case of the cranks at right angles, although the temperature range was practically the same in the two cases. However, the subject was worthy of more consideration and a more mathematical analysis, as he believed it contained the answer to practically the whole of the much debated question of initial condensation. The remarks of Mr. Sinton were answered by Prof. Weighton, and did not require, he thought, any further reply from him. With regard to the point raised by Mr. Griffith, he thought the chief reason for adopting the cranks at right angles in the two-cylinder compound engine in preference to the cranks opposite was on account of the better turning moment the former arrangement gave, and the greater ease with which it was started. At present several high-speed engine-builders were adopting the cranks opposite style in compound engines, thereby obtaining better balance and a higher mechanical efficiency, and probably a greater steam economy, and getting over the difficulty of the uneven turning moment by putting on a large fly-wheel. He did not think that by enlarging the receivers in the College engine the efficiency of the cranks at right angles would be increased, as the first receiver was already extra large, and, so far as steam economy went, he thought that was all to be looked for in the less initial condensation in the high-pressure cylinder, upon which the size of the second and third receivers could have little or no effect. The gain in mechanical efficiency must also be independent of the size of the receivers. He had hoped that the advocates of high pressures would have had something to say; but perhaps they were now convinced that there was a good deal of economy to be got with pressures of 150 to 180 lbs. This was all he had to say; and he would, in conclusion, again thank them for the courteous manner in which they had received the paper.

On the motion of the PRESIDENT, a hearty vote of thanks was accorded by acclamation to Mr. A. L. Mellanby for his paper.

CLOSING BUSINESS.

ALTERATIONS IN THE CONSTITUTION.

The PRESIDENT moved, on behalf of the Council, the following alteration in the Constitution :—

Article IX.—The Council of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, ~~nine~~ *eighteen* Vice-Presidents, fifteen Ordinary Members of Council, and an Honorary Treasurer.

Mr. ROBT. THOMPSON seconded, and the alteration was agreed to.

The PRESIDENT moved the following alteration :—

Article X., first paragraph.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Ordinary Members of Council shall be elected annually. The retiring Vice-Presidents *shall be those who have served six years*, and Ordinary Members of Council ~~shall be~~ those who have served three years from their last election.

Mr. WM. BOYD said he had an amendment to move in the spirit of the alteration. As the wording stood at present, it hardly met the requirements of the case. He would just occupy their attention for a moment whilst he explained what he meant. They were aware that the Vice-Presidents had hitherto been nine in number. By a resolution passed at the last General Meeting that number was doubled, and became eighteen, and there had just been elected three new Vice-Presidents to replace those who would now retire under the old rule and nine new ones. The consequence was they had twelve new Vice-Presidents coming in at that meeting. When the next election came on, according to the reading of this rule as at present drawn, the retiring Vice-Presidents would be those who had served for six years. Now, at that time there would be no Vice-Presidents who had served for six years, consequently the Council would have to ballot from among the whole number of eighteen as to which should retire. By the operation of that ballot the three members to retire might fall upon those gentlemen whom they had just had the pleasure of electing with a view to strengthen the Vice-Presidents of the Council and the Institution generally—one or more of these might be balloted out after having been only one year in office. He thought it exceedingly desirable to avoid such a possibility, and had to propose that the three members

who would retire next year should be those who would do so in the ordinary course under the existing rules, viz., those elected in May, 1896. Then at the end of the session in May, 1900, those three Vice-Presidents who were elected in 1897 would retire in their turn; then when they came to the session of 1901 they would have the twelve men just now elected, all having served an equal time. They would have to be balloted for as to which three should retire, and the same thing would operate in 1902 and 1903. In 1904 the last of the twelve now newly elected would come out of office in due course, and in subsequent years they would fall back upon the three longest in office. After consultation with Mr. Duckitt, his amendment would be upon the words printed in italics, and would read thus :—"The retiring Vice-Presidents *shall be those who have been in office for the longest period.*" Next year those would retire who were elected in 1896 and the following year it would be those who were elected in 1897, and so on (as explained above), until May, 1904, at which date and subsequently there would be found each year three Vice-Presidents who had been six years in office, and these would be those who had "served for the longest period," and those words, he thought, would meet the case. They had had this matter thrashed out at the last Council Meeting, and the Council agreed to this alteration which he had proposed, subject to the approval of the General Meeting. It was arranged that he should move a resolution to that effect.

Prof. WEIGHTON had very much pleasure in seconding Mr. Boyd's proposal; he thought it would be a great improvement over the method indicated in the circular.

The PRESIDENT said that being the case, he would adopt Mr. Boyd's amendment, so that the resolution fell to the ground. When the rule was drafted the effect was not quite foreseen, and the Council quite recognised it would be injudicious to have such an operation as would have come about. He was, therefore, much obliged to Mr. Boyd for bringing the matter forward, and fully adopted his suggestion. He would, therefore, put it that the words Mr. Boyd had now read be inserted in the Article of the Constitution, and that this Article would then read :—"The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Ordinary Members of Council shall be elected annually. The retiring Vice-Presidents *shall be those who have been in office for the longest period*, and Ordinary Members of Council those who have served three years from their last election."

This was unanimously agreed to.

The PRESIDENT proposed the following alterations in the bye-laws :—

Bye-Law 11, second paragraph.—Any voting paper returning either more or less than one President, ~~nine~~ *eighteen* Vice-Presidents, one Honorary Treasurer, and fifteen Ordinary Members of Council shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President to a Member who is not elected President shall count to him as a Vice-President; the votes given as Vice-President or Treasurer to persons not so elected shall count to them as Ordinary Members of Council, unless they have just completed a term of office in such capacity.

Add to Bye-Law 33.—*A synopsis of the subject-matter of each paper shall be forwarded to the Secretary by the writer for insertion in the circular convening the meeting at which the paper is to be read.*

Mr. W. BOYD seconded, and the alterations were agreed to *nem. con.*

APPOINTMENT OF AUDITOR.

Sir B. C. BROWNE had great pleasure in moving the re-appointment of Mr. R. W. Sisson as Auditor. He was well known to most of them, and, he believed, had performed his duties exceedingly well. He had, therefore, much pleasure in moving the appointment.

Mr. ROBT. THOMPSON seconded, and the re-appointment was confirmed.

THE COUNCIL AND MEMBERSHIP.

The PRESIDENT declared the names of the gentlemen elected to fill the vacancies in the Council list as follows :—

President—SIR B. C. BROWNE, D.C.L.

Vice-Presidents—MESSRS. W. J. BONE, G. CLARK, A. COOTE, JOHN DICKINSON, C. D. DOXFORD, SIR WILLIAM GRAY, MESSRS. G. B. HUNTER, ARTHUR LAING, D. B. MORISON, JOHN TWEEDY, COL. P. WATTS, and MR. TOM WESTGARTH.

Hon. Treasurer—MR. G. E. MACARTHY.

Ordinary Members of Council—MESSRS. W. HÖK, W. C. MOUNTAIN, H. B. ROWELL, A. G. SCHAEFFER, and G. W. SIVEWRIGHT.

INSTALLATION OF THE NEW PRESIDENT.

The PRESIDENT said the announcement of the list of new officers of the Institution brought him now to what he might say was rather an important point in his career, as he had now to retire from the very honourable position in which they were good enough to place him two years ago; but in doing so it afforded him very great pleasure to have the opportunity to hand over the seals of office to a very old friend, a very distinguished member of the engineering profession, and a gentleman well known to every one of them. He could only say he was extremely glad, and he thought the Institution was to be congratulated upon being able to obtain Sir Benjamin Browne's assent to fulfil this very important office. During the two years he (Col. Swan) had had the honour of presiding over the Institution he had had very many pleasurable experiences, he had had many pleasant meetings and pleasant excursions; but the one thing that had been disappointing to him was this, that their meetings generally had been very badly attended. It seemed to him there was not that interest evinced in the Institution (as shown by the attendance at the meetings) as was desirable. In the last two years the number of members of one kind and another had risen from 985 to 1,073, or about 10 per cent. addition. Now, he had to say it was rather depressing that with an Institution having nearly 1,100 members, they could not, on such an occasion as this, raise a larger audience than they saw before them that night. He could not refrain from making these remarks, for he did feel that this Institution, as an educational establishment, ought to draw forth from the members a greater amount of interest than it actually had done up to this time. It could do an immense amount of good, and if the members would only come together and exchange ideas and have discussions, the meetings would become very interesting in themselves and so draw the members together. He, therefore, hoped that under the new *régime* now starting Sir Benjamin would have the pleasure of seeing larger audiences than had been his own lot, but all the same, he begged to thank those present, and the Council and Secretary, for all their kind co-operation during his term of office. It now only remained for him to ask them to accord to his successor the same kindness that they had accorded to him, with the addition of rather better attendances.

Sir B. C. Browne then took the chair.

The PRESIDENT (Sir B. C. Browne) said he could assure them he appreciated very much the honour they had done him in putting him in the position that evening which he now held for the first time. They had had many Presidents since the Institution first started, but in one way the selection they had now made was an exceptional one, for, although he had been a member of the Institution from its commencement, he was sorry to say that from personal reasons he had been able to take only a small part in the work and success of the Institution. The success had been very great, and for the honour of that he could lay very small claim indeed. He was on the Council for three years, and during part of that time he had the honour of being Mayor of Newcastle, and that was the only time he had been on the governing body of the Institution. The result was he took up this position with considerable diffidence and hesitation, for the same reason that had hitherto kept him back, and which, he was afraid, would operate against the efficiency of his work in the future. The fact was that for nearly the last twenty years he had had to choose between technical work and other affairs, and had had to give his attention to subjects equally important, equally arduous, but not so closely mixed up with technicalities as engineering or shipbuilding. However, he was proud of this Institution, he was proud of his connection with it as President, and no effort would be wanting on his part during his period of office for the success of the Institution. He was sorry to hear, as he had heard, what the ex-President said about the non-attendance. He was sorry, not only for their own sakes, but for the sakes of the younger members of the Institution. During the course of a long life one observed a great many things, and one thing he observed was this, that those young men who began life and started early in the way of reading and discussing papers coincided very remarkably with those who, in after life, became the leading members in their profession. They must go back to a very early age to find Lord Armstrong's first paper in the annals of the Literary and Philosophical Society, and they would find that the training which came from writing papers and putting their ideas in black and white, and putting them before members of their own class with a view to discussion, was one of the best trainings to qualify them for promotion. Some felt too modest and diffident; some, he feared, felt that their ideas were too important, and did not want to put them before other people; but, at the same time, he knew they were both wrong. When they got on in life, so large a part of their success depended not only on their knowledge, but also on how to impress other people, so as to give the public or customers

confidence in them. They learnt not only to know, but also how to express their knowledge. Sir George Humphrey, the great surgeon examiner at Cambridge, when he was told that this young man and that young man knew his subjects but could not well express what he knew, used to say, "If a man really understood his subject he could express what he knew. It was because his knowledge was slovenly that he could not express it. The young man that could not express what he knew was not fit to take charge of a patient whose confidence had to be gained." What applied to the doctor applied to the young engineer and shipbuilder. Every engineer and draughtsman should try to work up some subject in which he felt he excelled, and then put it into black and white and bring it before his comrades for free discussion. He hoped they would have a keen competition in the way of reading papers, and have numerous meetings and good discussions. It was just what they should expect in Newcastle, which was looked upon as the cradle of engineering, to keep up that high position which it always had maintained in the eyes of the world. Much depended upon the young members of the profession. He thanked them for the position in which they placed him.

VOTE OF THANKS.

Mr. Robt. Thompson said, in moving a vote of thanks to their retiring President, he had a very pleasant duty to perform. He was quite sure that any one who had been through two years of office as President, and who had so much business as Col. Swan had to attend to, must find it a great tax upon his time, and the meetings of the Institution would frequently be attended at considerable inconvenience. The President was also expected to attend the annual meetings of other institutions, and in this their President had been very industrious. He (Mr. Thompson) had been at several meetings of the Institution, and thought the President very painstaking, giving every member a chance of speaking. He admitted that his own attendance had not been what he should have liked. Circumstances, however, had not been favourable for his attendance for the past few months, but those who had been present had, he knew, been struck with the value of the papers read on shipbuilding and engineering subjects, and he thought himself that they were equal to any they had had in past sessions. He was sorry that the attendance of members had not been up to what they should expect, and what he, the President, anticipated. He trusted that the incoming